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TRIAXIAL COMPRESSIVE STRENGTH AND DIRECT SHEAR TESTS ON AGNICO-EAGLE CRUSHED ROCK

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13 pp

MICROMEDIA

TRIAXIAL COMPRESSIVE STRENGTH AND DIRECT SHEAR TESTS ON AGNICO-EAGLE CRUSHED ROCK

by

JOHN LEBLANC* DAN MILLETTE** AND ALFRED ANNOR***

ABSTRACT

Triaxial compressive strength and direct shear tests were conducted on crushed rock material. This material was received at MRL's Sudbury Lab from the AGNICO-EAGLE Mines in Quebec. The results of both tests are presented in this report.

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Keywords: triaxial compressive strength, direct shear, crushed rock, Mohr-Coulomb curve

ESSAIS DE RÉSISTANCE À LA COMPRESSION TRIAXIALE ET DE CISAILLEMENT DIRECT SUR DE LA PIERRE CONCASSÉE DE LA AGNICO-EAGLE

par

JOHN LEBLANC*, DAN MILLETTE** ET ALFRED ANNOR***

RÉSUMÉ

On a effectué des essais de résistance à la compression triaxiale et des essais de cisaillement direct sur des échantillons de pierre concassée fournis au Laboratoire de Sudbury (LRM) par la société AGNICO-EAGLE Mines, du Québec. Le rapport présente les résultats de ces essais.

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Mots clés : résistance à la compression triaxiale, cisaillement direct, pierre concassée, courbe de Mohr-Coulomb

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INTRODUCTION

1.0 INTRODUCTION

Four cases of crushed rock material were delivered to the Sudbury Laboratory on July 10, 1991 from Agnico-Eagle Mines in Cadillac, Que. to be used for establishing the shear strength properties of this material. The rock was tested for moisture content, which was determined to be 0.2%. Two samples were removed from these cases to be used for direct shear tests while the remainder was used for triaxial compressive strength tests. The triaxial compression tests were conducted to collaborate the shear parameters which have been established from the shear box tests.

TEST PROCEDURES

2.1 Sieving Analysis

Prior to triaxial and direct shear tests, sieve analysis was completed on the first sample of rock. The material was split, and sifted through a series of 13 sieves ranging from 12.5 mm down to 38 microns. This sample was used for three preliminary direct shear tests and for test numbers 1, 2 and 3.

A portion of the second sample was then split and sifted through the same series of sieves to determine a size distribution. This sample was used for direct shear tests 4 through 9.

2.2 Direct Shear Testing

The direct shear testing was done in sets of three tests each to enable plotting of a Mohr-Coulomb envelope from which a shear angle and a cohesion value could be determined. From the first sample, three tests were completed to ensure correct operation of the direct shear testing apparatus and also to get an indication of material properties. The calculation sheets and other data tables are included in a separate report [4].

Each set of direct shear tests involved three measurements using the following normal loads: 4, 7, and 10 kg weights which give normal stresses of 46.84, 76.24, and 105.64 kPa, respectively. The average bulk density of the crushed rock samples before and after applied load are summarized in Table 1.

Table 1 Bulk Densities of the Crushed Rock Materials For the Direct Shear Tests.

Crushed Rock Material	Bulk Density Before Applied Load (kg/m^3) (Average)	Bulk Density After applied load (kg/m^3) (Average)
Loose, Dry @	(1440)	(1567)
46.8 kPa	1420	1500
76.2 kPa	1500	1620
105.6 kPa	1400	1580
Compacted, Dry @	(1890)	(1933)
46.8 kPa	1860	1890
76.2 kPa	1910	1950
105.6 kPa	1900	1960
Compacted, Wet @	(1633)	(1700)
46.8 kPa	1670	1700
76.2 kPa	1610	1660
105.6 kPa	1620	1740

The 3 sets of shear tests (7, 8 and 9) were completed using material from the second crushed rock sample. This material was dried in a vacuum oven to ensure 0% moisture content. It was then weighed and water added to bring the moisture content to exactly 5% by weight. After each test, the material was returned to the sample container, dried in the oven to 0% moisture content, weighed and the appropriate amount of water added to bring the moisture content back to 5%.

The material was placed in the shear box in three separate lifts. After each lift was placed, the shear box was placed on a vibrating table and vibrated for thirty seconds at 3600 cycles per minute at maximum amplitude using a surcharge pressure of 12.57 kPa. The stress Vs displacement graphs for the three sets of the direct shear measurements are appended to this report.

2.3 Triaxial Compressive Test Procedures

The procedure used to test the material for triaxial compressive strength was similar to that of Lambe and also CANMET's Pit Slope manual [1,2]. This procedure is commonly used for soil testing. Since the material was in the form of loose crushed rock, some adaptations to the procedures were required. These procedures are discussed in a separate report [3].

2.3.1 Sample Preparation For Triaxial Tests

The material was consolidated by vibration into 6 inch diameter by 12 inch long specimens. The average bulk densities of the cylinders are summarized in Table 2. There were six specimens tested, three were dry (as received) and three were tested with a moisture content of 5 percent by weight. The three confining pressures used for these tests were 75.8, 151.6 and 227.5 kPa. In all cases, the samples were allowed to drain during the test.

Table 2 Bulk Density of the Crushed Rock Material For The Triaxial Compression Tests

Crushed Rock Samples	Bulk Density Before Applied load (kg/m^3) (Average)	Bulk Density After Applied load (kg/m^3) (Average)
(Dry)	(1765)	(1846)
1	1711	1853
2	1785	1858
3	1799	1827
(Wet)	(1712)	(1957)
4	1663	1843
5	1710	2128
6	1763	1901

TEST RESULTS

3.0 TEST RESULTS

3.1 Sieving Analysis

For the first sample, the results of the sieve analysis is presented in Figure 1. The coefficient of curvature (C_c) was determined to be 1.03 while the coefficient of uniformity (C_u) was 10.0. The results of the sieve analysis for the second sample is shown in Figure 2; the C_c and C_u were found to be 1.28 and 13.79 respectively. The triaxial compression tests were conducted on crushed rock material with similar gradation as shown in Figure 1 and 2.

3.2 Direct Shear Test Results

Three sets of direct shear tests (1, 2 and 3) were done using the unconsolidated material from the first rock sample. This material was dried and therefore contained no moisture. Figure 3 shows Mohr-Coulomb envelope for the loose rock material. The friction angle was found to be 38.7° and the cohesion was 3.8 kPa. Figure 4 show the results of the test 4, 5, and 6 using consolidated dry material. The shear angle was determined to be 46.4° and the apparent cohesion was 11.6 kPa. Figure 5 show the results of tests 7, 8 and 9. The shear angle was found to be 15.5° and the cohesion 17.9 kPa, respectively. Figure 6 shows the composite graph of direct shear tests for loose dry, compacted dry and compacted wet rock material. The results of each of the samples tested are presented in Table 3 and the shear stress versus displacement relationship for each test are presented in appendix B.

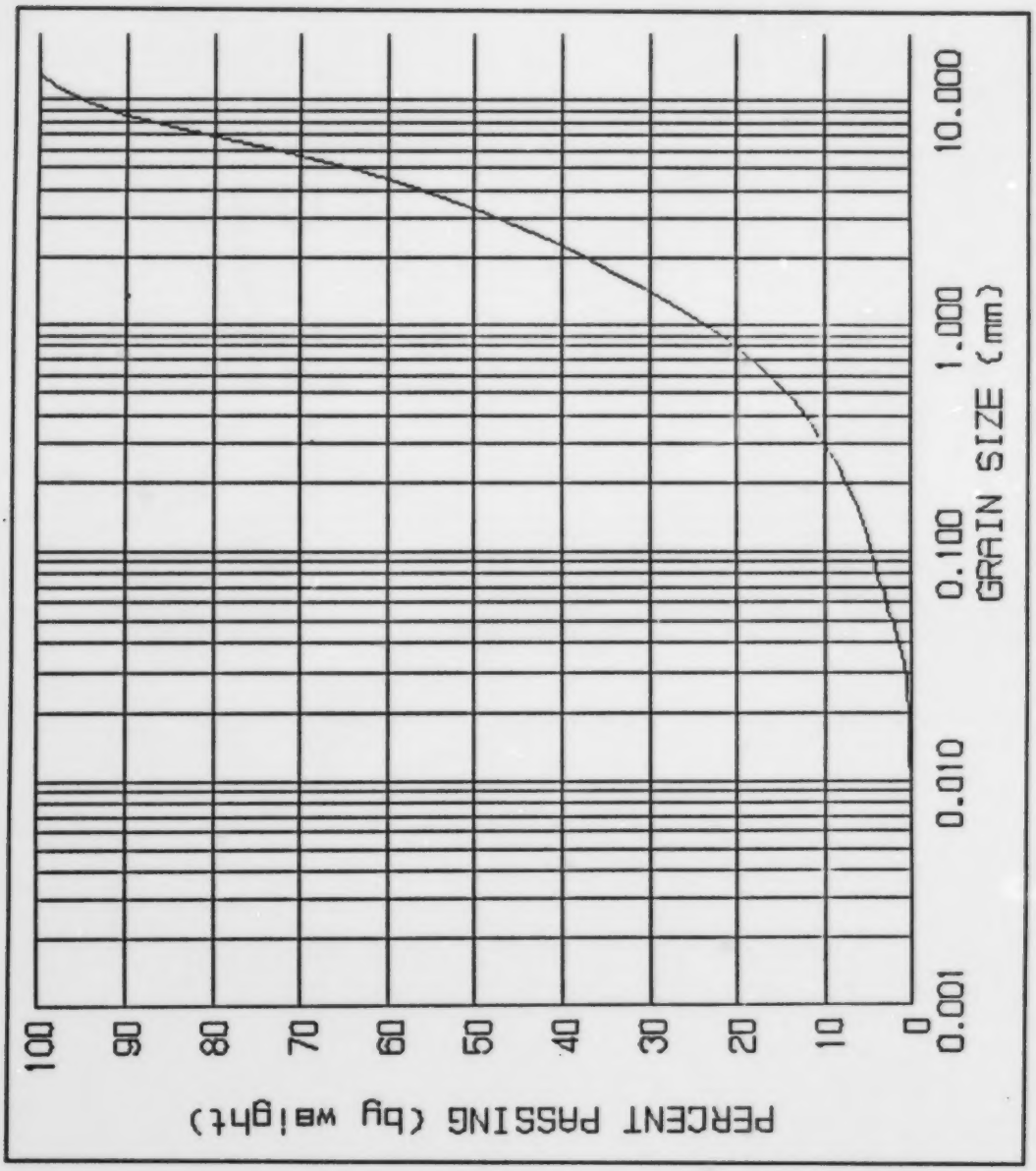

Figure 1 Sieve Analysis of Sample #1

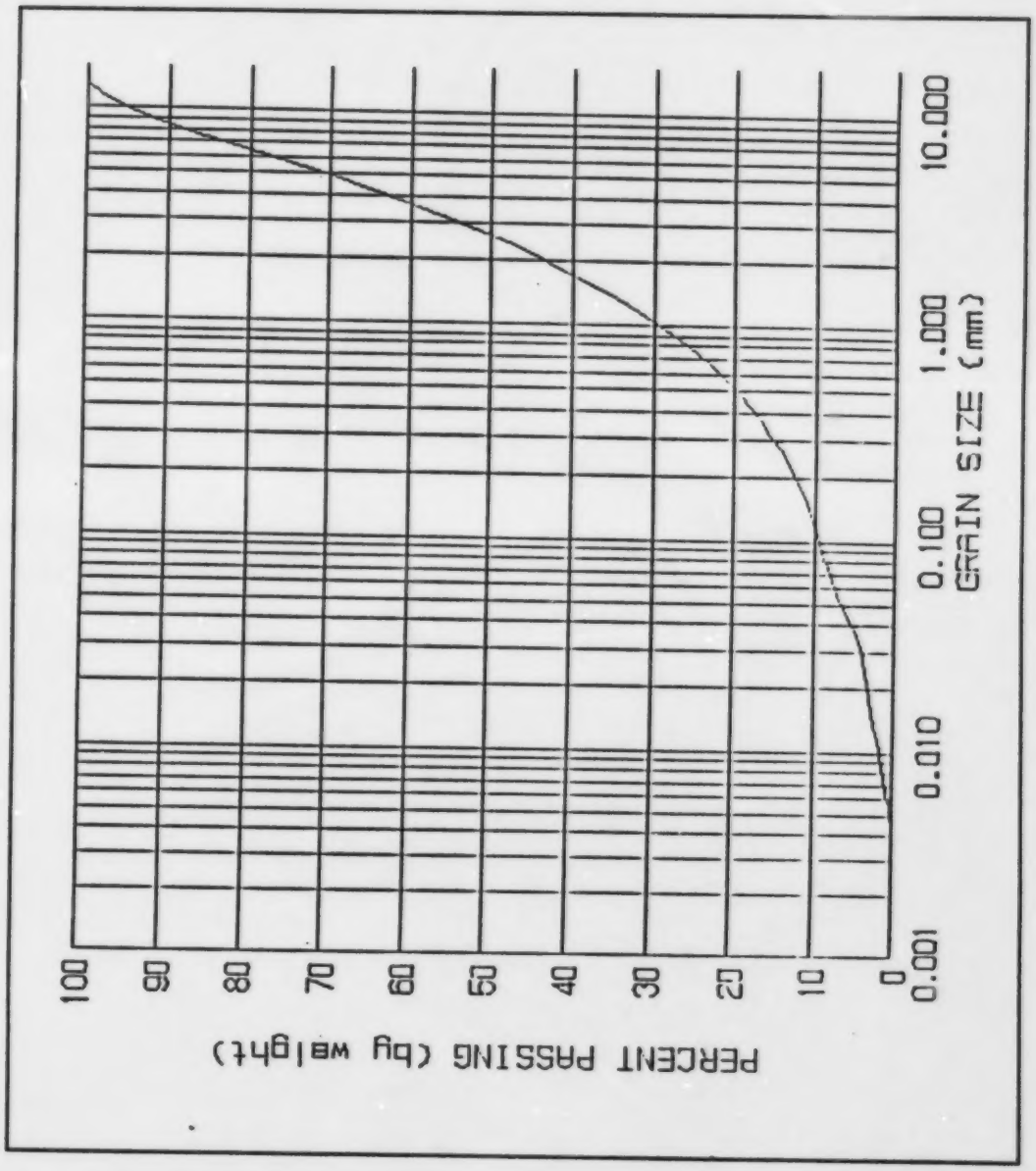

Figure 2 **Sieve Analysis of Sample #2**

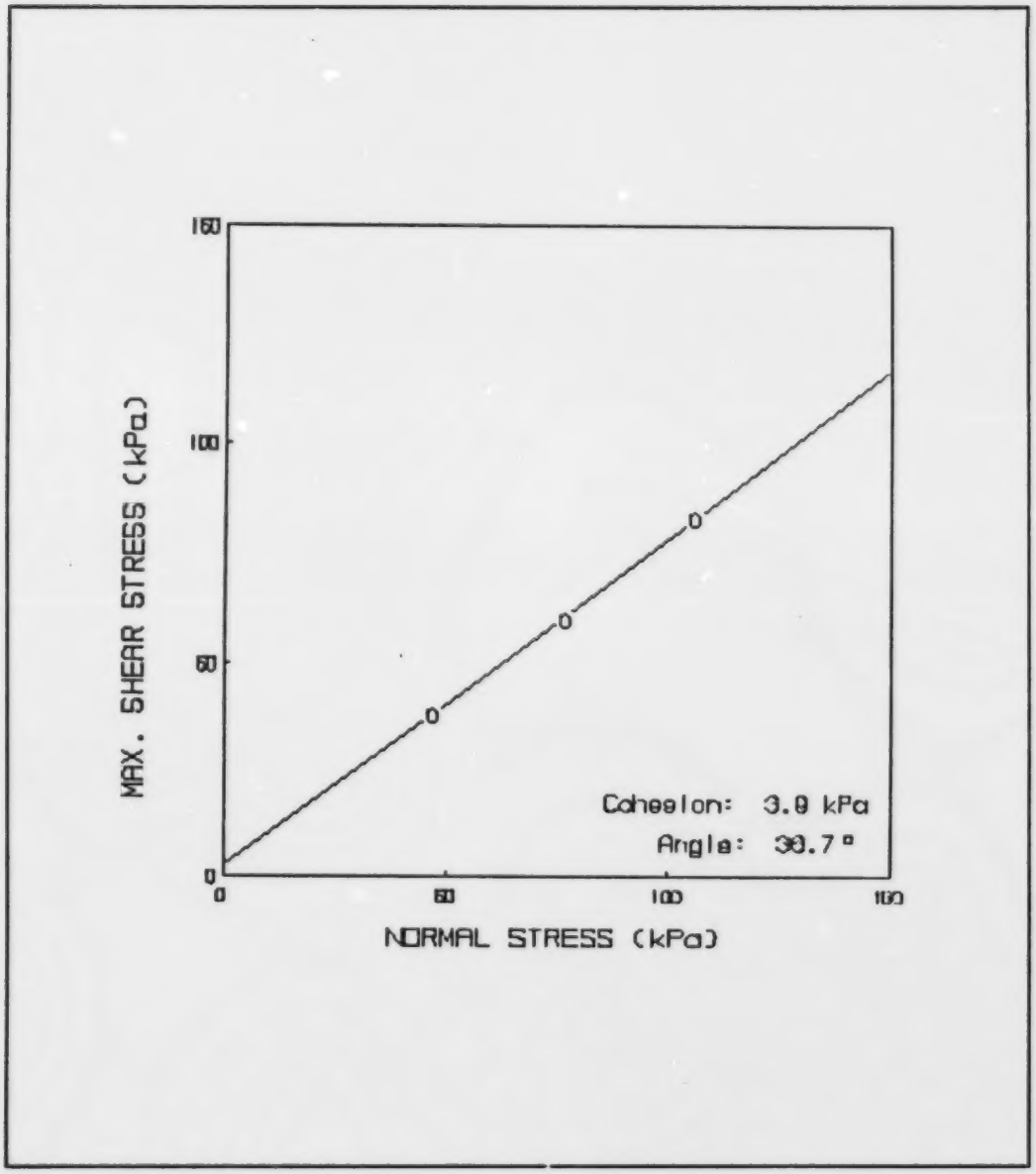

Figure 3 Mohr-Coulomb Envelope For Direct Shear Test On Loose, Dry Crushed Rock Sample.

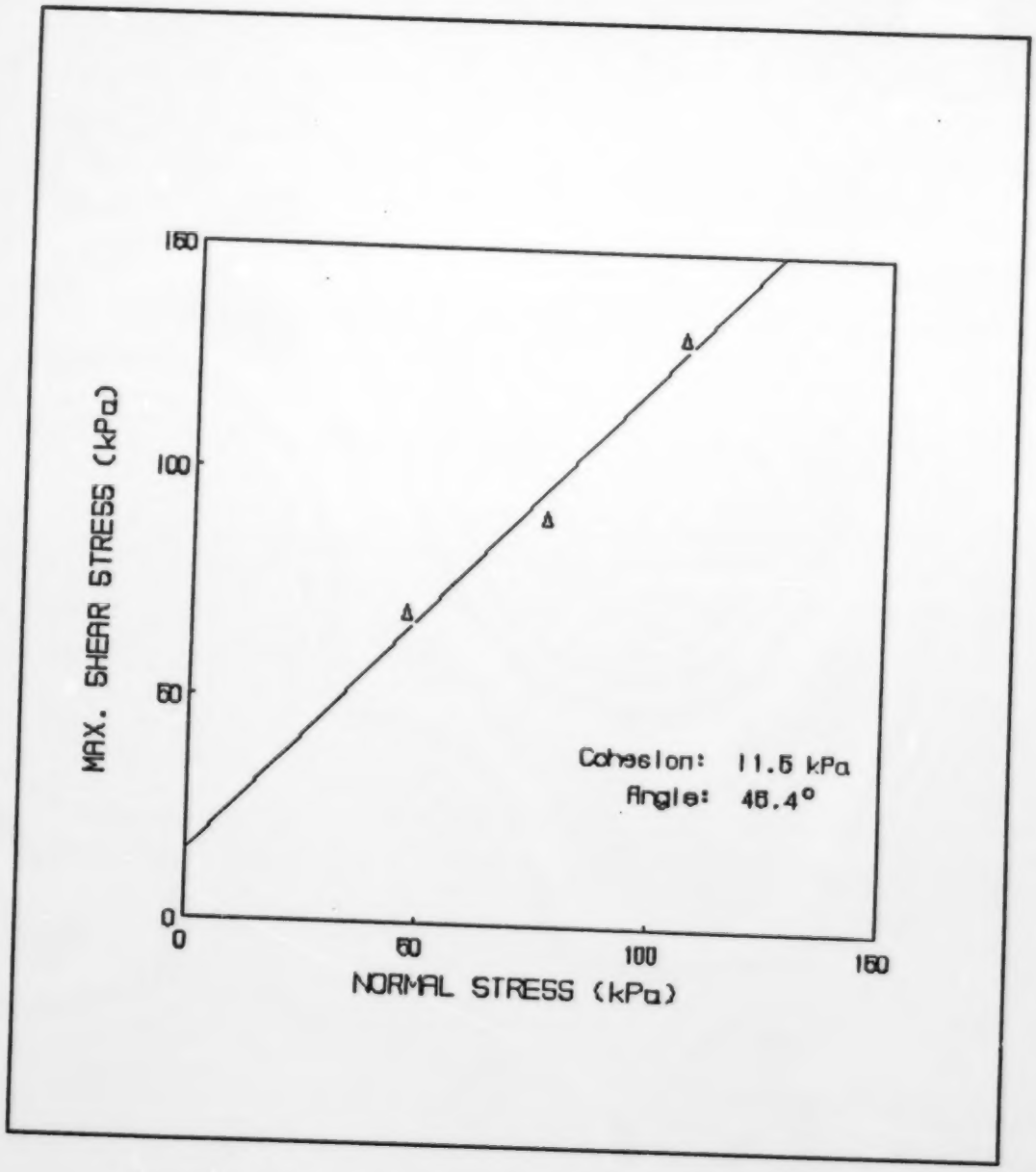

Figure 4 Mohr-Coulomb Envelope For Direct Shear Test On Compacted, Dry Crushed Rock Sample.

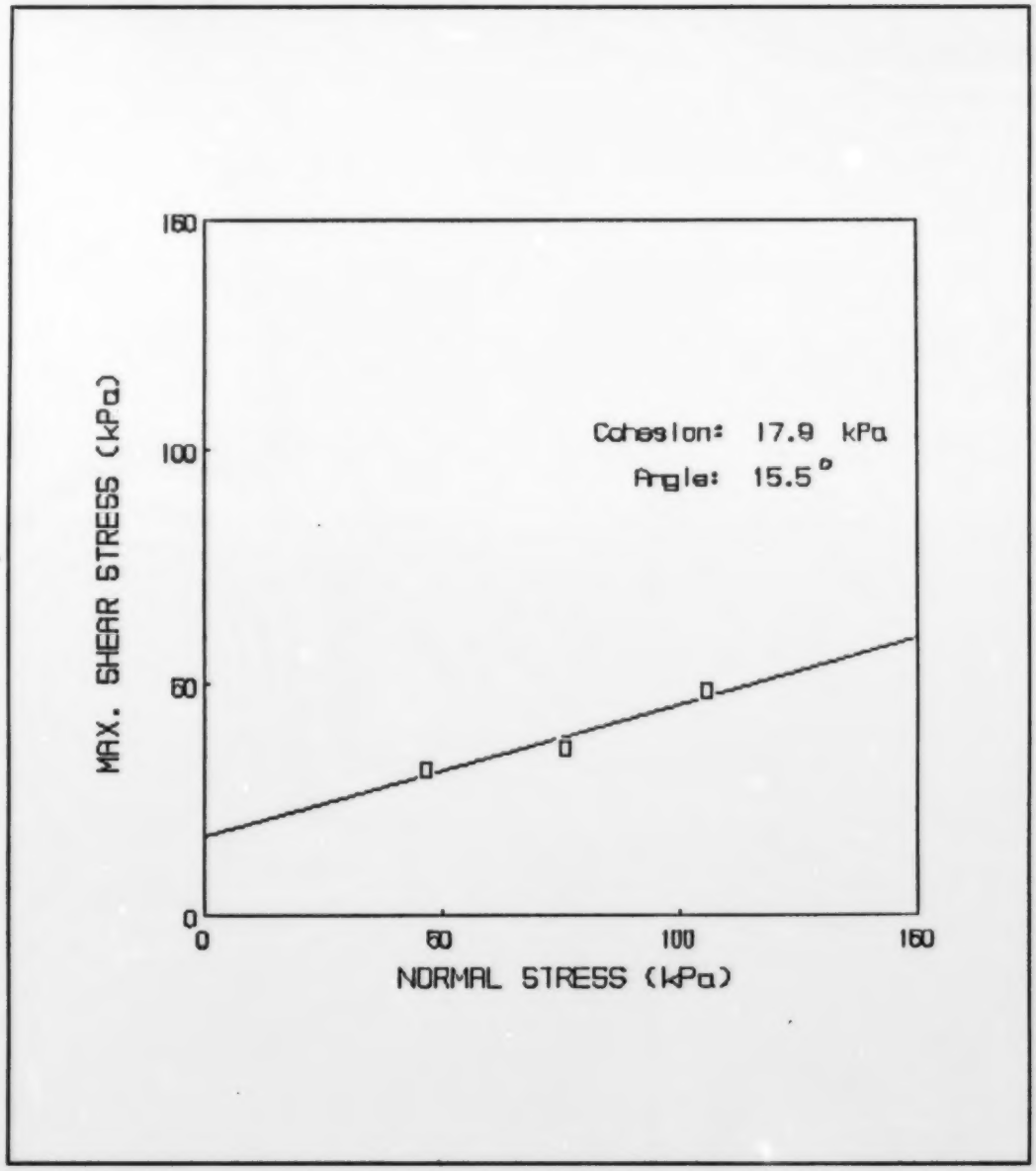

Figure 5 Mohr-Coulomb Envelope For Direct Shear Test On Compacted, Wet Crushed Rock Sample.

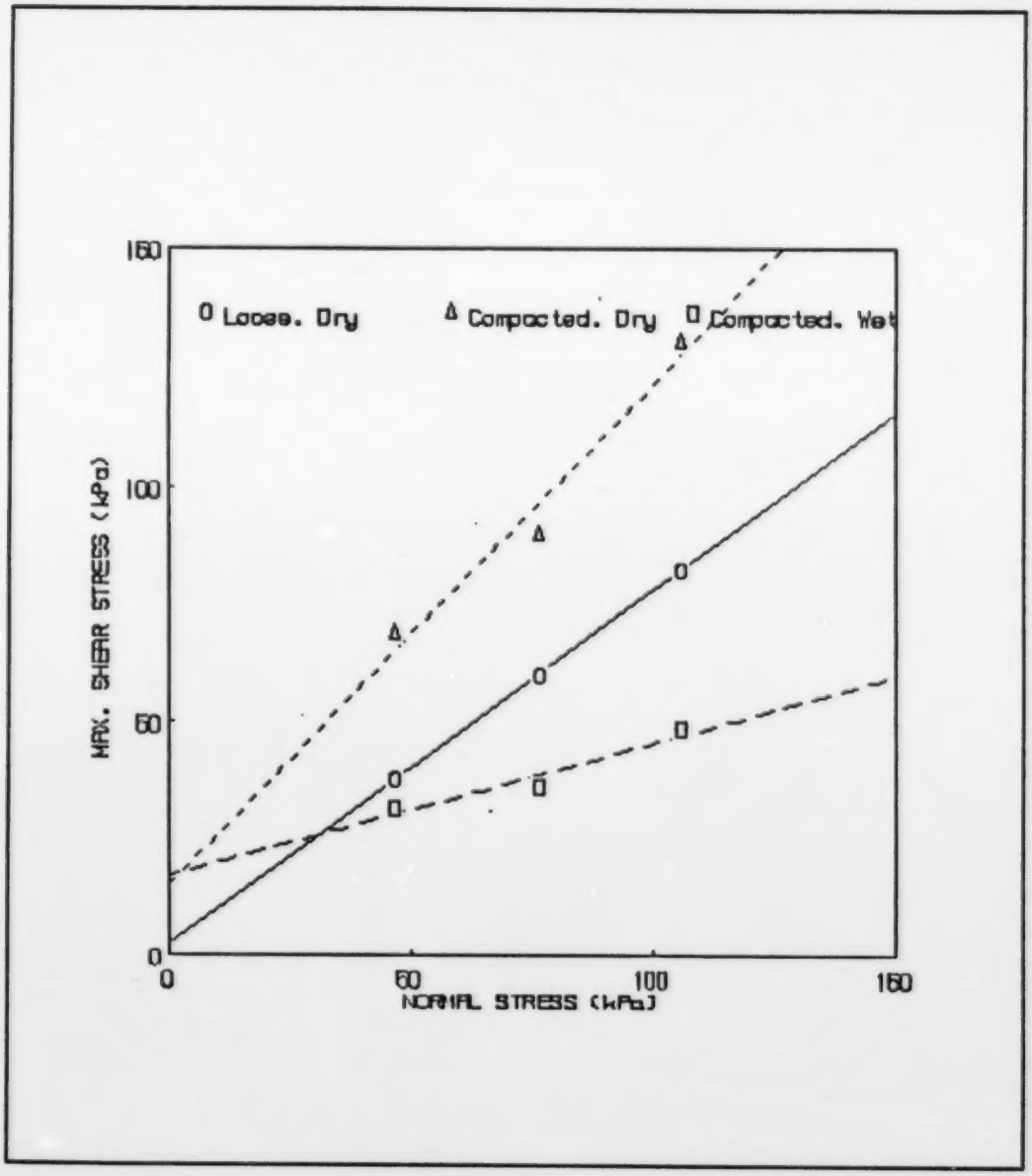

Figure 6 Composite Graph of the Mohr-Coulomb Envelope For Direct Shear Test Crushed Rock Sample.

Table 3 Direct Shear Test Results

	Sample	Normal Stress (kPa)	Maximum Shear stress (kPa)	Internal friction angle (°)	Apparent cohesion (kPa)
Loose Dry	1	46.8	38.4		
	2	76.2	60.3	38.7	3.8
	3	105.6	82.8		
Compacted	4	46.8	68.7		
dry	5	76.2	90.6	46.4	11.6
	6	105.6	131.1		
compacted	7	46.8	32.4		
5%	8	76.2	36.6	15.5	17.9
moisture	9	105.6	49.2		

3.3 Triaxial Compression Test Results

Mohr - Coulomb plots for the dry rock material from the triaxial tests are shown in Figure 7 & 8. The internal angle of friction was found to be 38° and the apparent cohesion was 18 kPa. For the rock material containing 5% moisture content, the average internal angle of friction was found to be 26° and the apparent cohesion was 22 kPa. The stress versus strain relationship for each of the triaxial compression tests are presented in Appendix C. The apparent roughness of the curves is probably due to the nature of the material being analyzed. Table 4 summarizes the results for each of the triaxial tests.

Table 4 Triaxial Compressive Strength Test Results
Mohr-Coulomb Parameters

Sample	Normal Stress (kPa)	(Peak) Maximum Shear Stress (kPa)	Deviator Stress (kPa)	Internal friction angle (°)	Apparent Cohesion (kPa)
(dry)					
1	75.8	464.0	388.2		
2	151.6	759.0	607.4	38	18
3	227.5	1095.0	867.5		
5% Mois.					
4	75.8	278.0	202.2		
5	151.6	586.0	434.4	26	22
6	227.5	653.0	425.5		

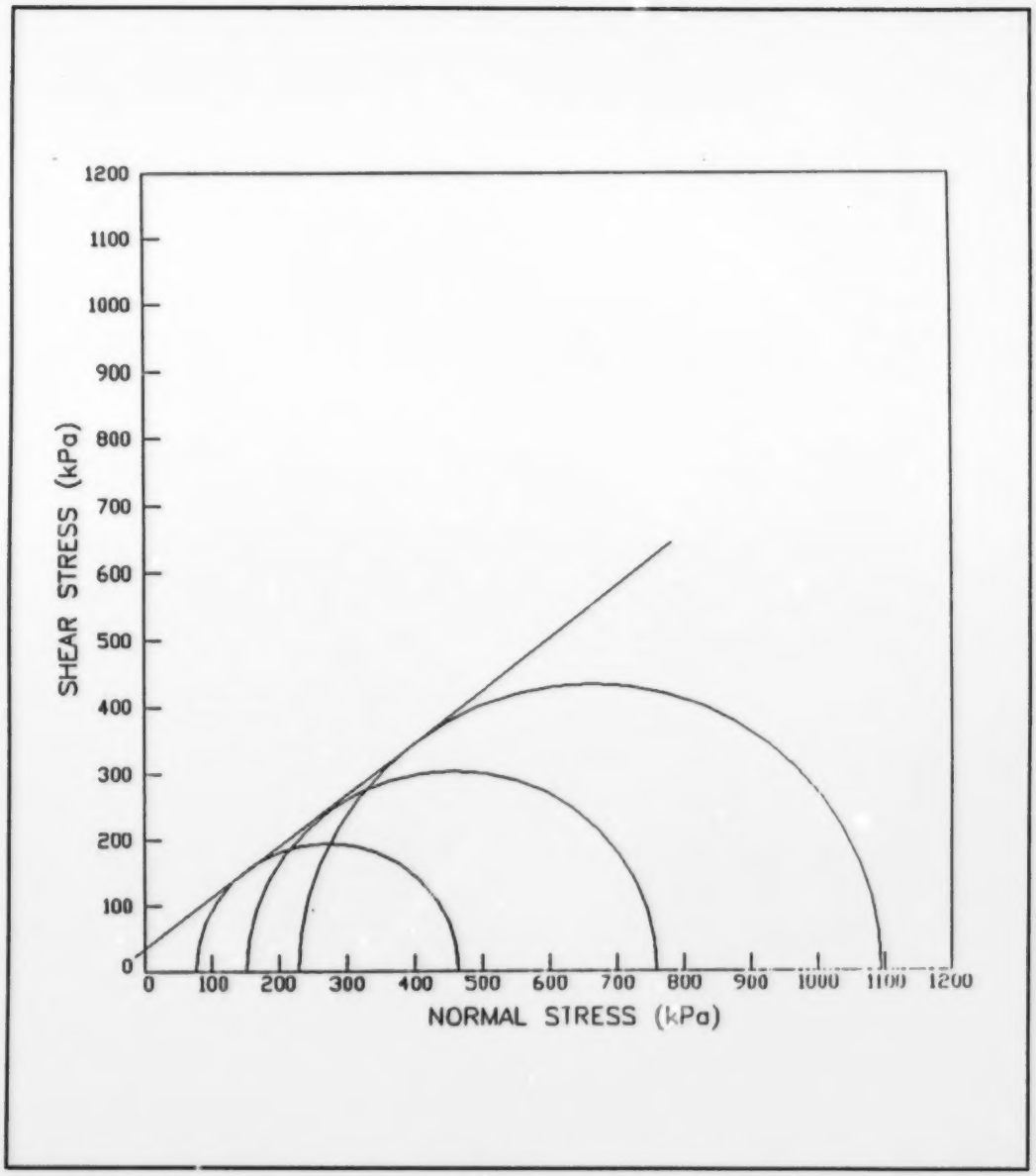

Figure 7 Mohr-Coulomb Envelope For Triaxial Test On Compacted, Dry Crushed Rock Sample.

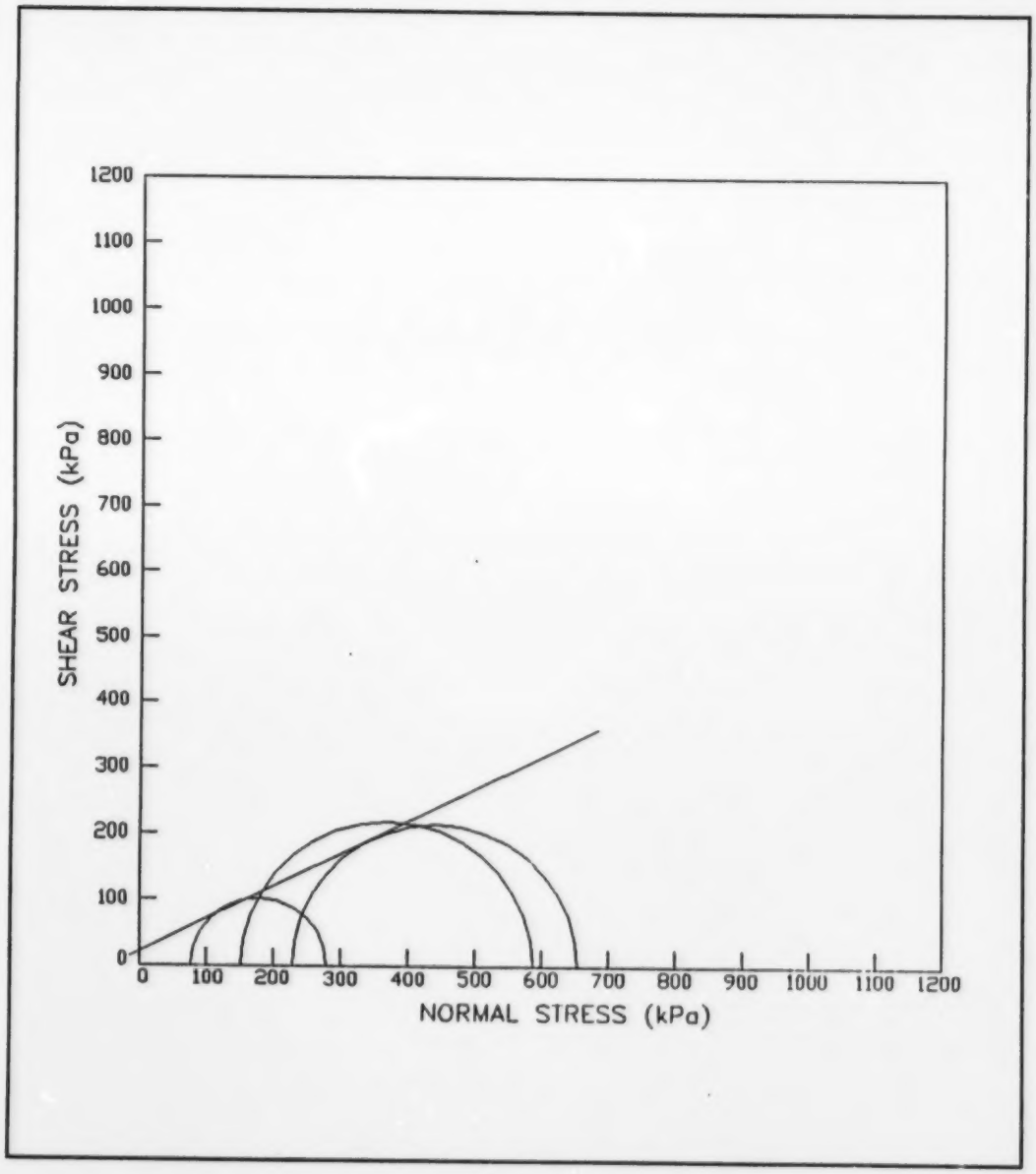

Figure 8 Mohr-Coulomb Envelope For Triaxial Test On 5% Moisture Content Crushed Rock Sample.

OBSERVATIONS

4.0 OBSERVATIONS

The shear strength parameters for the crushed rock material are summarized in Tables 3 and 4. There is generally a good agreement between the direct shear test results and those obtained from the triaxial compression tests. The agreement is more prominent for the dry crushed rock than the wet rock material.

The angles of internal friction for the compacted dry rock material were similar for both the shear box and triaxial compression tests. The value obtained from the triaxial compression test results is 38°. This is to be compared with a value of 46.4° for the direct shear measurements. The differences in the internal friction angle values can be attributed to the differences in the stress levels at which the tests were conducted.

The triaxial compression tests were performed at higher confining pressures than the normal stresses used for the direct shear tests (Table 3 and 4). The shear parameters of granular materials are influenced by the shape of particles, gradation and density. They are also affected by the level of stress. The slight differences in the bulk densities could also have contributed to the differences in the angle of internal friction values. The average bulk density of the compacted dry rock for the direct shear test was 1890 kg/m^3. This is to be compared to a value of 1765 kg/m^3 for the triaxial compression measurements.

With regard to the wet crushed rock, both test methods produced a low friction angle value than was observed for the dry material. The friction angle values for the direct shear tests and triaxial compressive strength tests were 15.5° and 26°, respectively. These differences can be attributed to differences in bulk densities of the test samples.

The apparent cohesion strength values ranged from 12 kPa to 22 kPa.

Both the direct shear test and triaxial compression test results suggest that the shear properties of the crushed rock material from the Agnico Eagle Mines are very dependent on the moisture content.

ACKNOWLEDGEMENTS

The assistance of Soutsay Boualavong in preparing this report is acknowledged and much appreciated.

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5.0 REFERENCES

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APPENDIX A

MECHANICAL ANALYSIS

Sample No.: 01 **Test Date:** July 16, 1991

Project: Agnico-Eagle Project **Sample Origin:** Cadillac, Que

Description of Sample: Mine Rock (Shist)

Tested by _____

Wt. of dry sample + container	1715.30 g
Wt. of Container	83.88 g
Wt. of Dry Sample	1631.42 g

Sieve analysis and grain shape

Sieve No.	Wt. Sieve Only	Wt. Sieve + Sample	Material Wt.	% Retained	Cummulative
12.5 mm	487.52 g	487.52 g	0.00 g	0.0	0.0
9.5 mm	487.77	582.26	94.49	5.8	5.8
4.75mm	495.20	1017.20	522.00	32.0	37.8
2.36mm	443.77	786.60	342.83	21.0	58.8
1.18mm	403.22	643.40	240.18	14.7	73.5
600 um	354.39	521.13	166.74	10.2	83.7
300 um	333.49	434.55	101.06	6.2	89.9
212 um	304.06	338.66	34.60	2.1	92.0
150 um	311.24	339.81	28.57	1.8	93.8
75 um	304.24	342.14	37.90	2.3	96.1
63 um	304.76	315.43	10.67	0.7	96.8
53 um	300.17	307.99	7.82	0.5	97.3
38 um	301.19	320.72	19.53	1.2	98.5
Pan	284.84	309.87	25.03	1.5	100.0

MECHANICAL ANALYSIS

Sample No.: 02 **Test Date:** July 22, 1991

Project: Agnico-Eagle Project **Sample Origin:** Cadillac, Que

Description of Sample: Mine Rock (Shist)

Tested by : [signature]

Wt. of dry sample + container	1007.80 g
Wt. of Container	54.92 g
Wt. of Dry Sample	953.08 g

Sieve analysis and grain shape

Sieve No.	Wt. Sieve Only	Wt. Sieve + Sample	Material Wt.	% Retained	Cummulative
12.5 mm	487.52 g	00.00 g	0.00 g	0.0	0.0
9.5 mm	487.76	569.93	82.17	8.6	5.8
4.75mm	495.18	737.71	242.53	25.4	31.2
2.36mm	443.78	644.80	201.02	21.1	52.3
1.18mm	403.15	551.15	148.00	15.5	67.8
600 um	354.40	453.08	98.68	10.4	78.2
300 um	333.49	395.91	62.42	6.5	84.7
212 um	304.04	325.51	21.47	2.3	87.0
150 um	311.26	328.49	17.23	1.8	88.8
75 um	304.21	329.88	25.67	2.7	91.5
63 um	304.72	312.77	8.05	0.8	92.3
53 um	300.06	305.69	5.63	0.6	92.9
38 um	301.00	320.45	19.45	2.0	94.9
Pan	284.86	305.78	20.92	2.2	97.1

APPENDIX B

Test #: 01
Date: July 15, 1991
Project: Agnico-Eagle

Wt. of Beaker & Backfill: 1545.7 g
Wt. of Beaker & Remainder: 1176.0 g
Wt. of Fill in Shearbox: 369.70 g

Height from Top of Box: 0.7839 cm
Change in Height w/ Applied Load: 0.95 cm

Volume of Material: 242.88 cc

Shearing Speed: 1.0 mm/min
Normal Load: 4.0 kg

TIME	VERTICAL DISPL.	FORCE (kN)	STRESS (kPa)
0	0.00	0.00	0.0
30	1.08	0.24	7.2
60	1.21	0.56	16.8
90	1.31	0.73	21.9
120	1.38	0.85	25.5
150	1.43	0.91	27.3
180	1.48	1.01	30.3
210	1.50	1.08	32.4
240	1.52	1.15	34.5
270	1.53	1.20	36.0
300	1.54	1.24	37.2
330	1.53	1.28	38.4
360	1.52	1.30	39.0
390	1.50	1.33	39.9
420	1.49	1.33	39.9
450	1.49	1.35	40.5
480	1.46	1.41	42.3
510	1.44	1.43	42.9
540	1.42	1.45	43.5
570	1.40	1.47	44.1
600	1.37	1.50	45.0
630	1.35	1.50	45.0
660	1.32	1.48	44.4
690	1.29	1.47	44.1
720	1.26	1.44	43.2
750	1.23	1.42	42.6
780			0.0
810			0.0
840			0.0

Max Shear Force: 1.5 mm (on proving ring)

Normal Force: 46.84 kN

Density Before Applied Load: 1.52 g/cc
Density After Applied Load: 1.58 g/cc

Int. Ang. Friction: 43.8 Degrees

Test #: 02
Date: July 15, 1991
Project: Agnico-Eagle

Wt. of Beaker & Backfill: 1176.0 g
Wt. of Beaker & Remainder: 761.7 g
Wt. of Fill in Shearbox: 414.30 g

Height from Top of Box: 0.8047 cm
Change in Height w/ Applied Load: 1.77 cm

Volume of Material: 240.80 cc

Shearing Speed: 1.0 mm/min
Normal Load: 10.0 kg

TIME	VERTICAL DISPL.	FORCE (kN)	STRESS (kPa)
0	0.00	0.00	0.0
30	0.01	0.07	2.1
60	0.10	0.49	14.7
90	0.27	0.98	29.4
120	0.39	1.28	38.4
150	0.47	1.52	45.6
180	0.55	1.71	51.3
210	0.61	1.90	57.0
240	0.65	2.04	61.2
270	0.69	2.13	63.9
300	0.72	2.22	66.6
330	0.74	2.32	69.6
360	0.77	2.43	72.9
390	0.78	2.51	75.3
420	0.80	2.55	76.5
450	0.82	2.65	79.5
480	0.82	2.69	80.7
510	0.83	2.74	82.2
540	0.83	2.76	82.8
570	0.83	2.80	84.0
600	0.82	2.81	84.3
630	0.80	2.82	84.6
660	0.79	2.87	86.1
690	0.77	2.84	85.2
720	0.76	2.85	85.5
750	0.75	2.85	85.5
780	0.75	2.85	85.5
810	0.75	2.87	86.1
840			0.0

Max Shear Force: 2.87 mm (on proving ring)

Normal Force: 105.64 kN

Density Before Applied Load: 1.72 g/cc
Density After Applied Load: 1.86 g/cc

Int. Ang. Friction: 39.2 Degrees

Test #: 03
Date: July 16, 1991
Project: Agnico-Eagle

Wt. of Beaker & Backfill: 760.7 g
Wt. of Beaker & Remainder: 378.2 g
Wt. of Fill in Shearbox: 382.54 g

Height from Top of Box: 0.7319 cm
Change in Height w/ Applied Load: 1.86 cm

Volume of Material: 248.08 cc

Shearing Speed: 1.0 mm/min
Normal Load: 7.0 kg

TIME	VERTICAL DISPL.	FORCE (kN)	STRESS (kPa)
0	0.00	0.00	0.0
30	0.11	0.48	14.4
60	0.25	0.70	21.0
90	0.36	0.85	25.5
120	0.45	0.98	29.4
150	0.52	1.09	32.7
180	0.58	1.16	34.8
210	0.64	1.26	37.8
240	0.68	1.38	41.4
270	0.74	1.44	43.2
300	0.78	1.52	45.6
330	0.81	1.61	48.3
360	0.83	1.68	50.4
390	0.86	1.76	52.8
420	0.88	1.78	53.4
450	0.90	1.75	52.5
480	0.91	1.82	54.6
510	0.92	1.83	54.9
540	0.93	1.89	56.7
570	0.94	1.92	57.6
600	0.95	1.90	57.0
630	0.97	1.87	56.1
660	0.99	1.94	58.2
690	1.00	1.93	57.9
720	1.02	1.97	59.1
750	1.05	1.99	59.7
780	1.08	2.05	61.5
810			0.0
840			0.0

Max Shear Force: 2.05 mm (on proving ring)

Normal Force: 76.24 kN

Density Before Applied Load: 1.54 g/cc
Density After Applied Load: 1.67 g/cc

Int. Ang. Friction: 38.9 Degrees

SHEAR BOX CALCULATIONS

Test #: 1
Date: July 16, 1991
Project: Agnico-Eagle

Wt. of Beaker & Backfill: 1358.1 g
Wt. of Beaker & Remainder: 996.0 g

Wt. of Fill in Shearbox: 362.10 g

Height from Top of Box: 0.7943 cm
Change in Height w/ Applied Load: 1.85 cm

Volume of Material: 241.84 cc

Shearing Speed: 1.0 mm/min
Normal Load: 7.0 kg

TIME	VERTICAL DISPL.	FORCE (kN)	STRESS (kPa)
0	0.00	0.00	0.0
30	0.07	0.37	11.1
60	0.23	0.68	20.4
90	0.33	0.75	22.5
120	0.38	0.86	25.8
150	0.48	1.04	31.2
180	0.57	1.15	34.5
210	0.64	1.23	36.9
240	0.71	1.32	39.6
270	0.75	1.41	42.3
300	0.81	1.48	44.4
330	0.86	1.53	45.9
360	0.90	1.60	48.0
390	0.93	1.65	49.5
420	0.96	1.70	51.0
450	0.98	1.75	52.5
480	1.00	1.80	54.0
510	1.01	1.83	54.9
540	1.02	1.86	55.8
570	1.04	1.89	56.7
600	1.05	1.88	56.4
630	1.06	1.94	58.2
660	1.07	1.96	58.8
690	1.08	1.95	58.5
720	1.09	1.93	57.9
750	1.10	1.96	58.8
780	1.10	2.01	60.3
810	1.12	2.00	60.0
840	1.14	1.99	59.7

Max Shear Force: 2.01 mm (on proving ring)

Normal Force: 76.24 kN

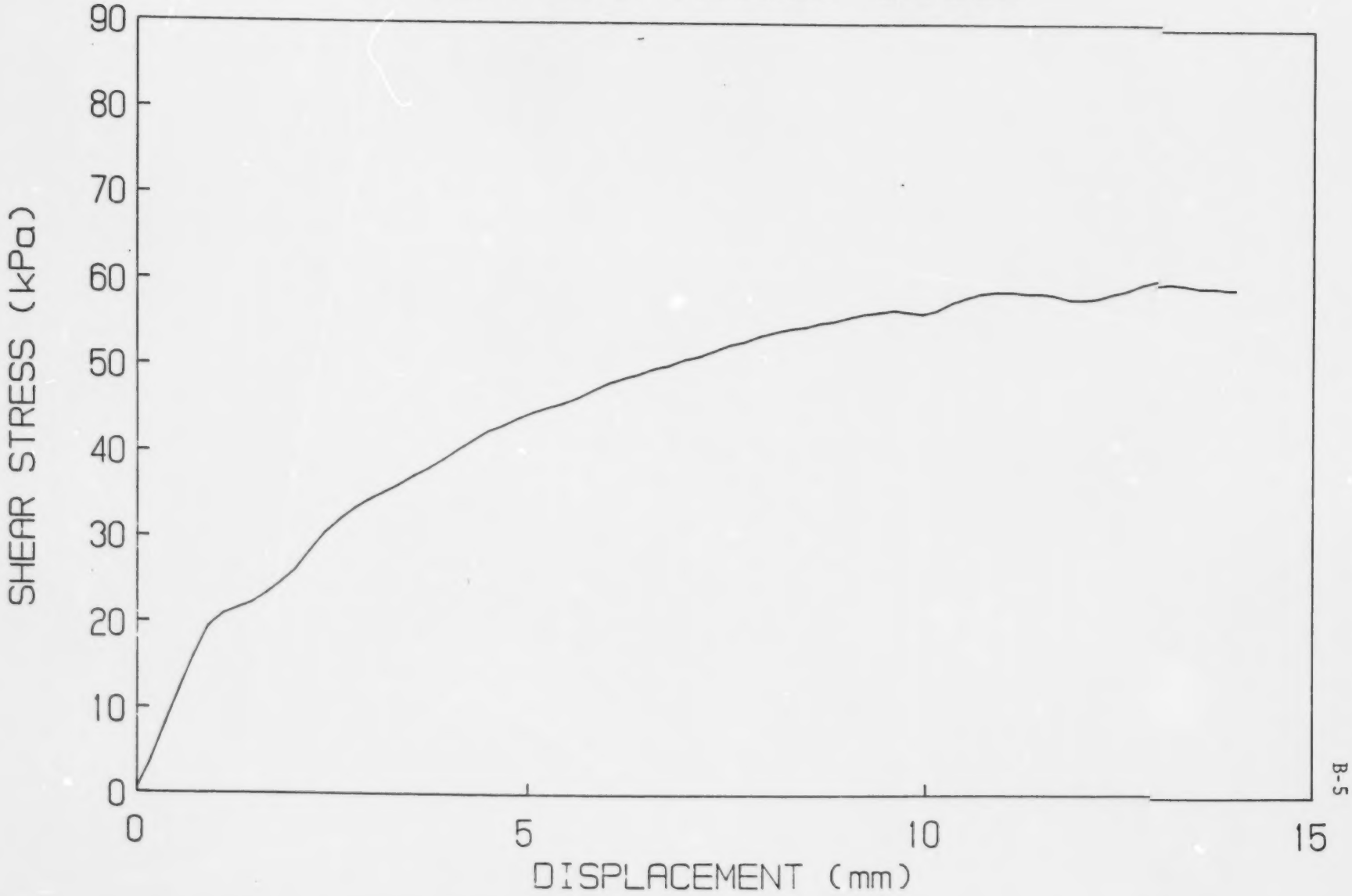
Density Before Applied Load: 1.50 g/cc
Density After Applied Load: 1.62 g/cc

Int Ang Frict: 38.3 Degrees

SHEAR BOX TEST #1

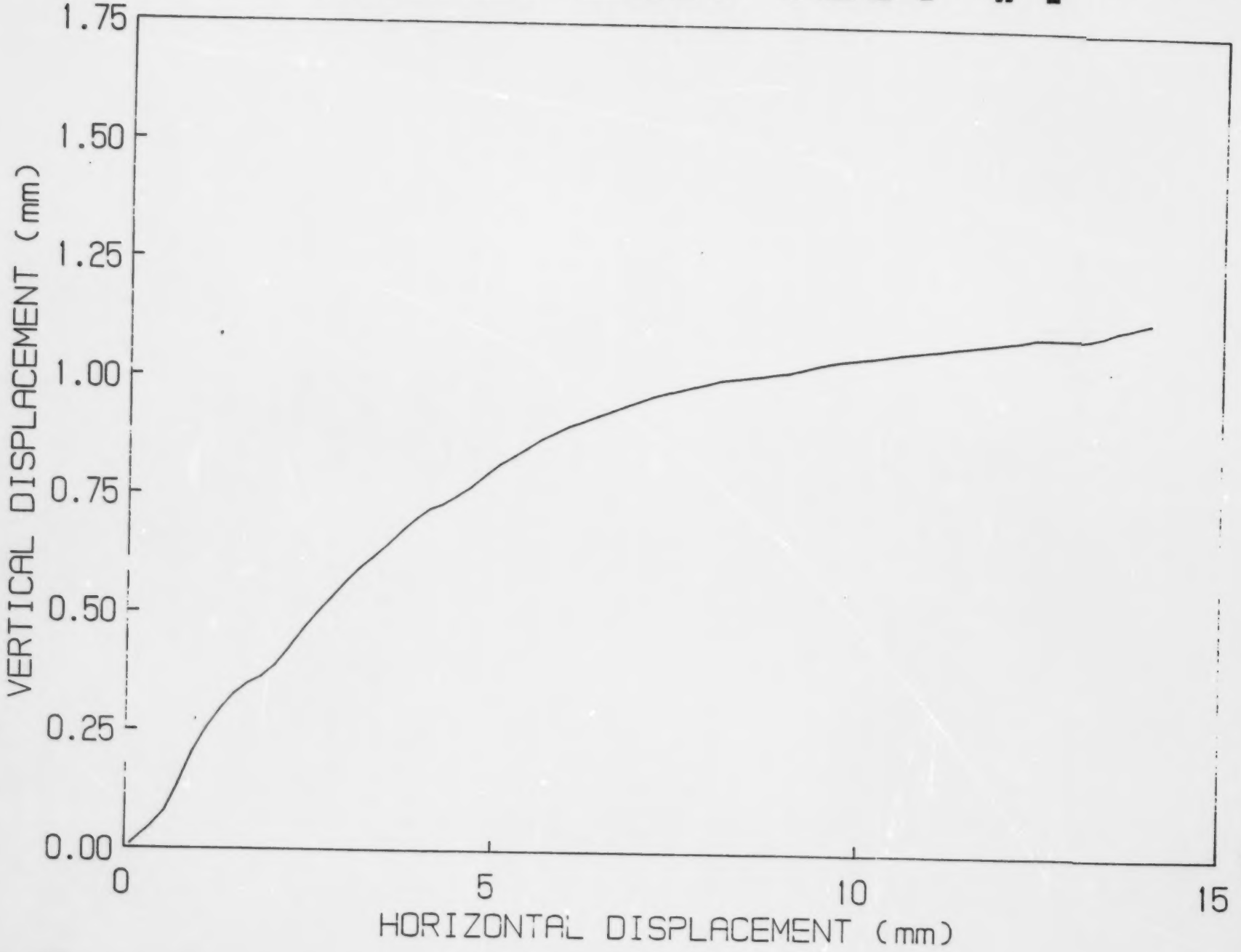
Loose Material

76.24 kPa Normal Stress



B-5

SHEAR-BOX TEST #1



SHEAR BOX CALCULATIONS

Test #: 2
Date: July 16, 1991
Project: Agnico-Eagle

Wt. of Beaker & Backfill: 995.9 g
Wt. of Beaker & Remainder: 648.0 g
Wt. of Fill in Shearbox: 347.90 g

Height from Top of Box: 0.7215 cm
Change in Height w/ Applied Load: 2.96 cm

Volume of Material: 249.12 cc

Shearing Speed: 1.0 mm/min
Normal Load: 10.0 kg

TIME	VERTICAL DISPL.	FORCE (kN)	STRESS (kPa)
0	0.00	0.00	0.0
30	0.01	0.03	0.9
60	0.08	0.56	16.8
90	0.25	1.02	30.6
120	0.39	1.32	39.6
150	0.50	1.54	46.2
180	0.59	1.67	50.1
210	0.66	1.80	54.0
240	0.71	1.92	57.6
270	0.75	2.00	60.0
300	0.80	2.08	62.4
330	0.83	2.16	64.8
360	0.87	2.24	67.2
390	0.89	2.28	68.4
420	0.91	2.33	69.9
450	0.93	2.34	70.2
480	0.94	2.42	72.6
510	0.97	2.54	76.2
540	0.98	2.60	78.0
570	0.98	2.66	79.8
600	0.98	2.62	78.6
630	0.99	2.65	79.5
660	0.99	2.70	81.0
690	1.00	2.69	80.7
720	1.01	2.73	81.9
750	1.02	2.73	81.9
780	1.02	2.76	82.8
810	1.02	2.67	80.1
840	1.04	2.65	79.5

Max Shear Force: 2.76 mm (on proving ring)

Normal Force: 105.64 kN

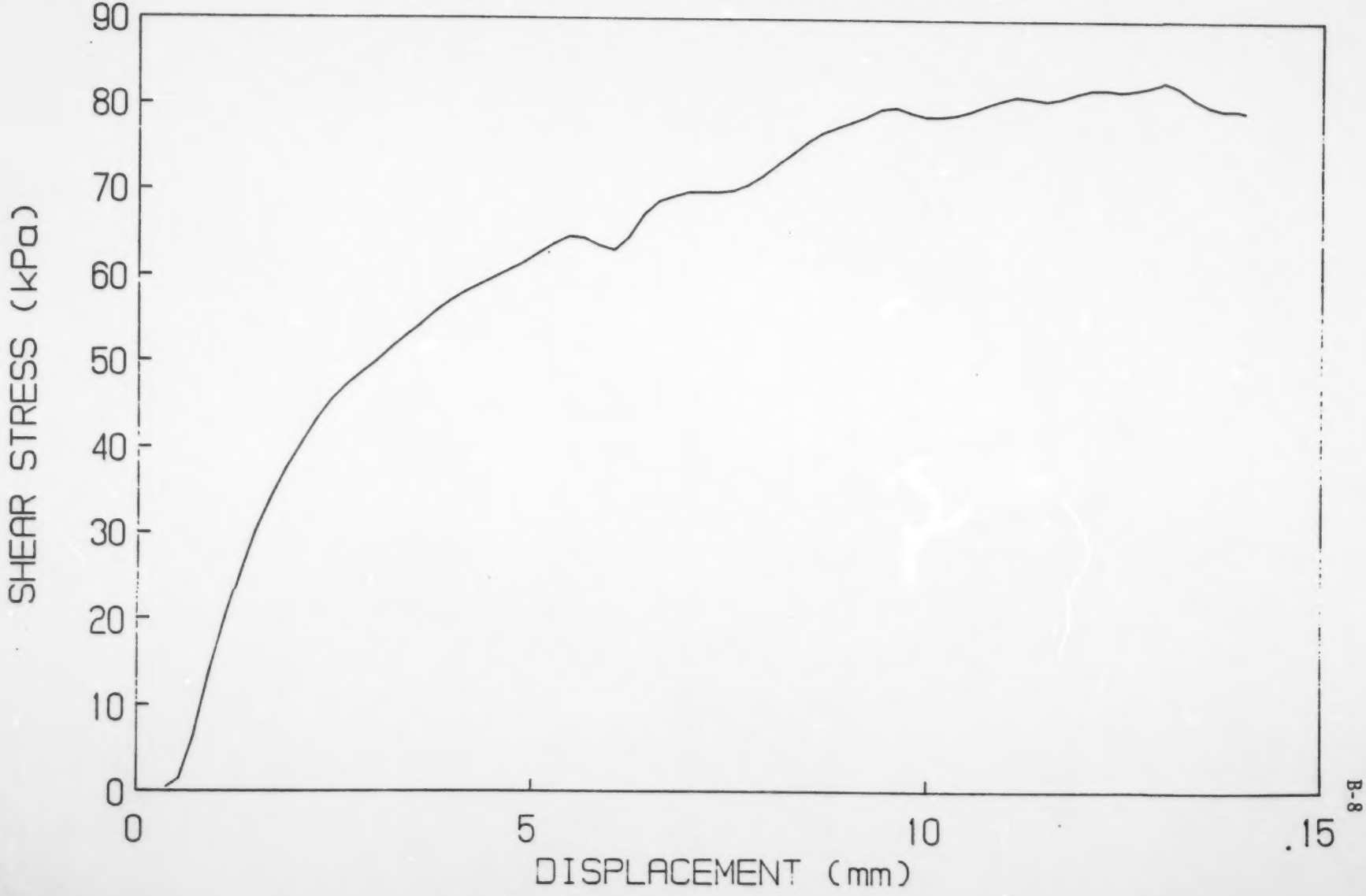
Density Before Applied Load: 1.40 g/cc
Density After Applied Load: 1.58 g/cc

Int. Ang. Friction: 38.1 Degrees

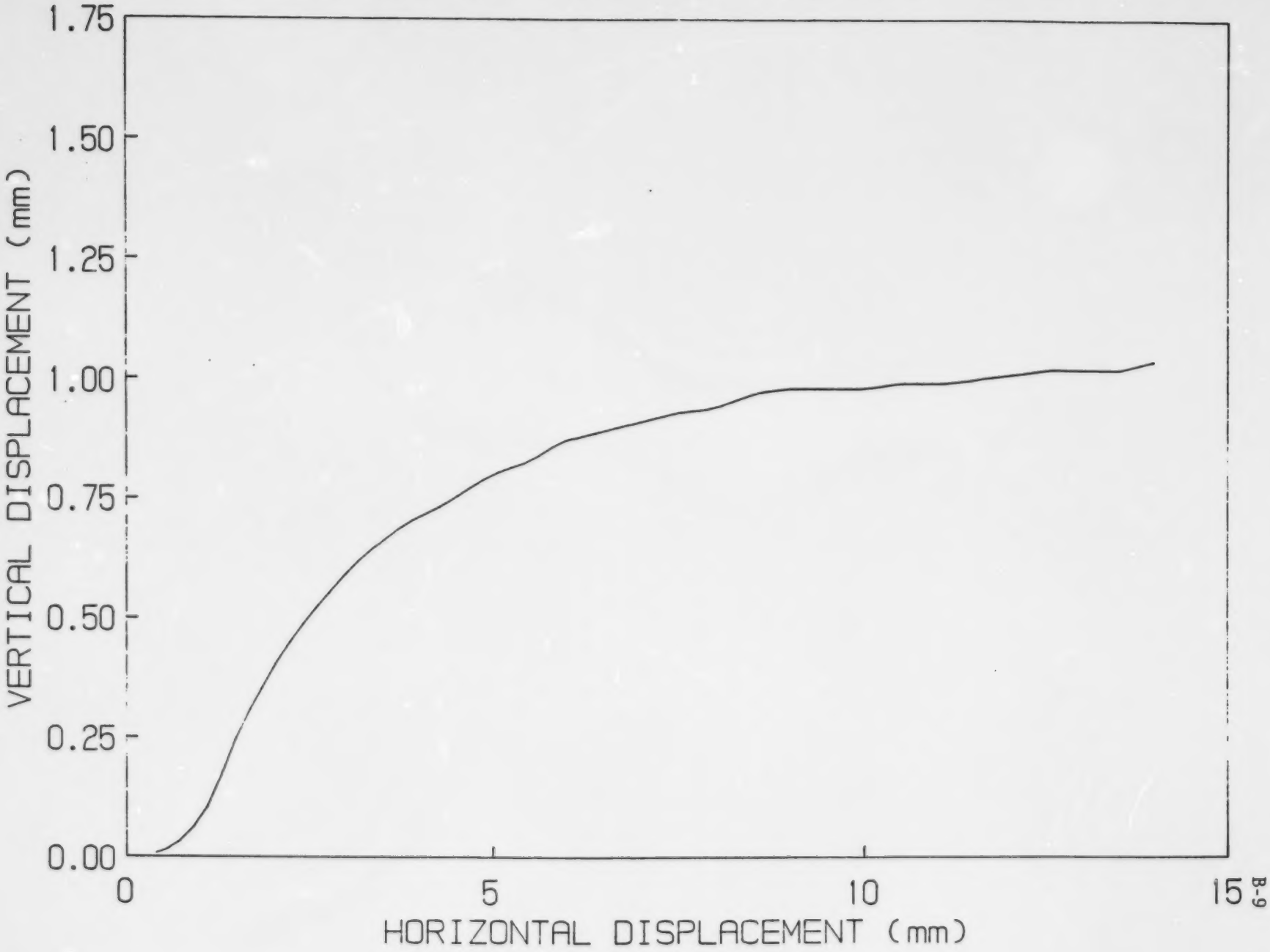
SHEAR BOX TEST #2

Loose Material

105.64 kPa Normal Stress



SHEAR BOX TEST #2



Test #: 3
Date: July 16, 1991
Project: Agnico-Eagle

Wt. of Beaker & Backfill: 612.6 g
Wt. of Beaker & Remainder: 259.2 g
Wt. of Fill in Shearbox: 353.43 g

Height from Top of Box: 0.7215 cm
Change in Height w/ Applied Load: 1.32 cm

Volume of Material: 249.12 cc

Shearing Speed: 1.0 mm/min
Normal Load: 4.0 kg

TIME	VERTICAL DISPL.	FORCE (kN)	STRESS (kPa)
0	0.00	0.00	0.0
30	0.01	0.04	1.2
60	0.15	0.39	11.7
90	0.31	0.58	17.4
120	0.43	0.70	21.0
150	0.53	0.78	23.4
180	0.60	0.84	25.2
210	0.65	0.88	26.4
240	0.70	0.92	27.6
270	0.74	0.95	28.5
300	0.78	0.98	29.4
330	0.80	1.02	30.6
360	0.82	1.04	31.2
390	0.84	1.07	32.1
420	0.85	1.10	33.0
450	0.87	1.13	33.9
480	0.88	1.15	34.5
510	0.89	1.17	35.1
540	0.90	1.19	35.7
570	0.92	1.17	35.1
600	0.93	1.21	36.3
630	0.94	1.21	36.3
660	0.95	1.21	36.3
690	0.96	1.22	36.6
720	0.96	1.23	36.9
750	0.97	1.25	37.5
780	0.98	1.25	37.5
810	0.99	1.27	38.1
840	0.99	1.28	38.4

Max Shear Force: 1.28 mm (on proving ring)

Normal Force: 46.84 kN

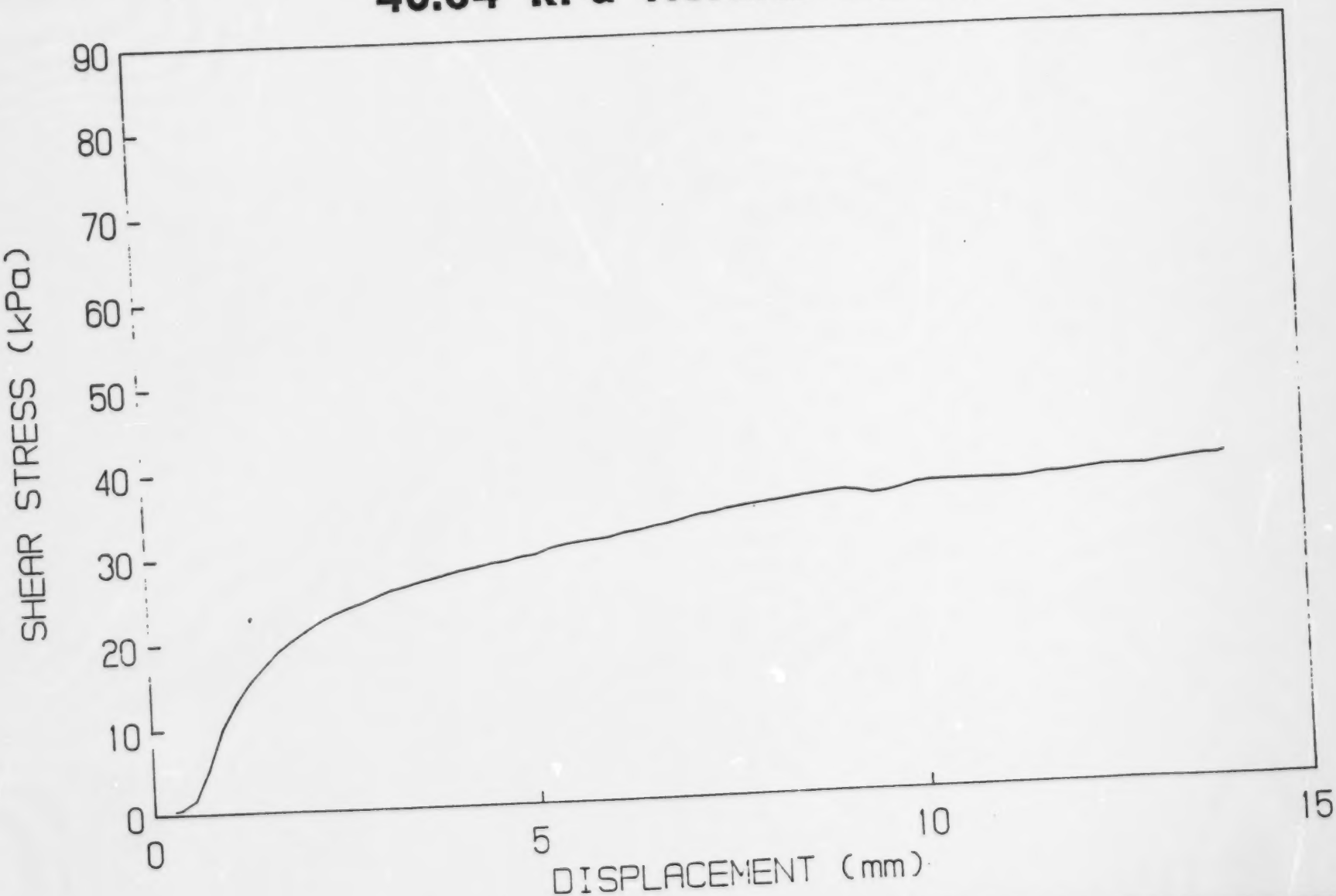
Density Before Applied Load: 1.42 g/cc
Density After Applied Load: 1.50 g/cc

Int. Ang. Friction: 39.3 Degrees

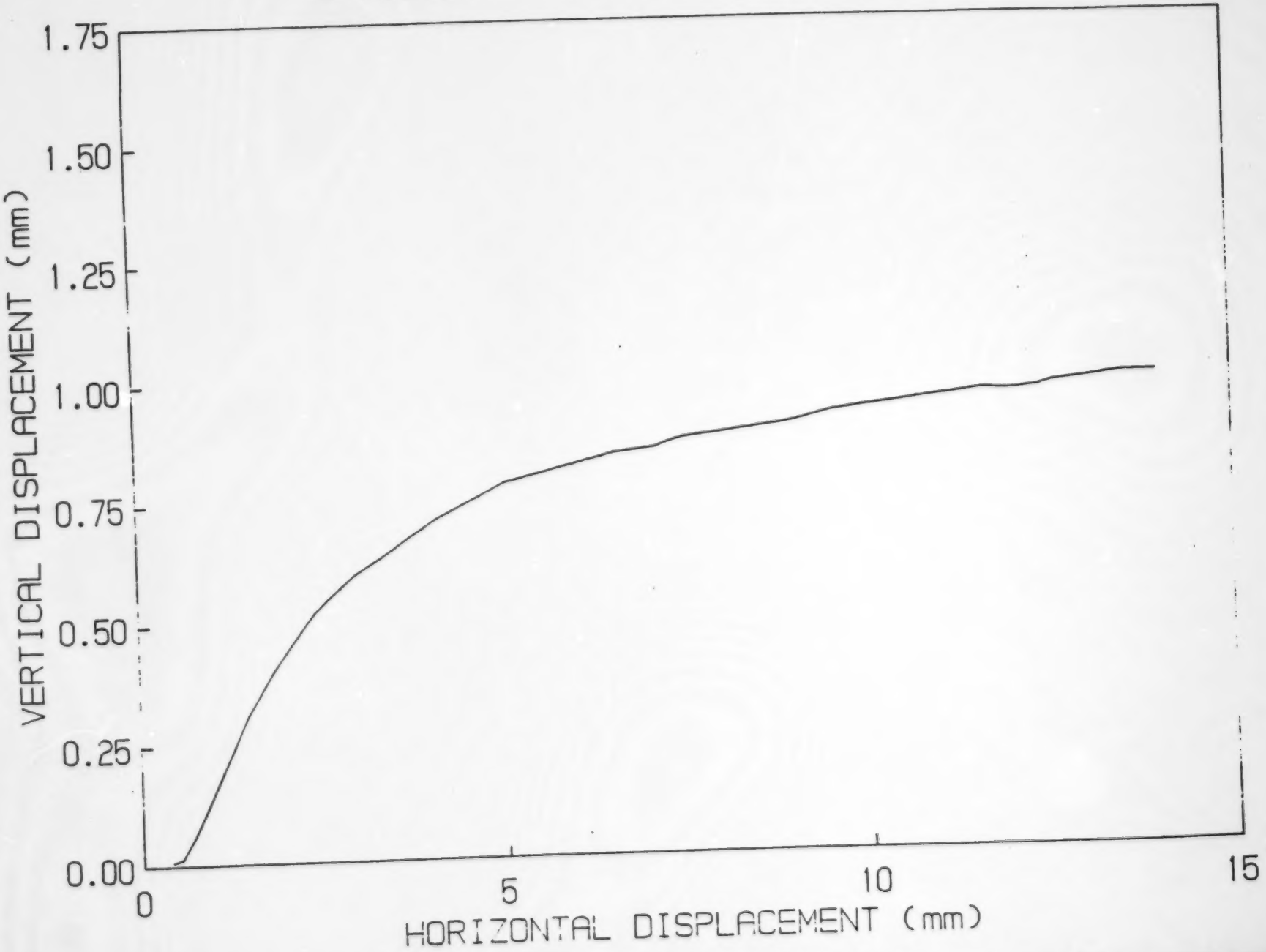
SHEAR BOX TEST #3

Loose Material

46.84 kPa Normal Stress



SHEARBOX TEST #3



Test #: 4
Date: July 22, 1991
Project: Agnico-Eagle

Wt. of Beaker & Backfill: 904.7 g
Wt. of Beaker & Remainder: 417.8 g
Wt. of Fill in Shearbox: 486.95 g

Height from Top of Box: 0.594 cm
Change in Height w/ Applied Load: 0.38 cm

Volume of Material: 261.87 cc

Shearing Speed: 1.0 mm/min
Normal Load: 4.0 kg

TIME	VERTICAL DISPL.	FORCE (kN)	STRESS (kPa)
0	0.00	0.00	0.0
30	0.05	0.30	9.0
60	0.09	0.70	21.0
90	0.11	0.99	29.7
120	0.11	1.19	35.7
150	0.08	1.42	42.6
180	0.04	1.57	47.1
210	0.00	1.67	50.1
240	-0.07	1.73	51.9
270	-0.15	1.81	54.3
300	-0.23	1.89	56.7
330	-0.31	1.94	58.2
360	-0.38	2.01	60.3
390	-0.45	2.07	62.1
420	-0.56	2.22	66.6
450	-0.63	2.28	68.4
480	-0.70	2.29	68.7
510	-0.78	2.22	66.6
540	-0.83	2.22	66.6
570	-0.90	1.99	59.7
600	-0.95	1.85	55.5
630	-0.99	1.78	53.4
660			0.0
690			0.0
720			0.0
750			0.0
780			0.0
810			0.0
840			0.0

Max Shear Force: 2.29 mm (on proving ring)

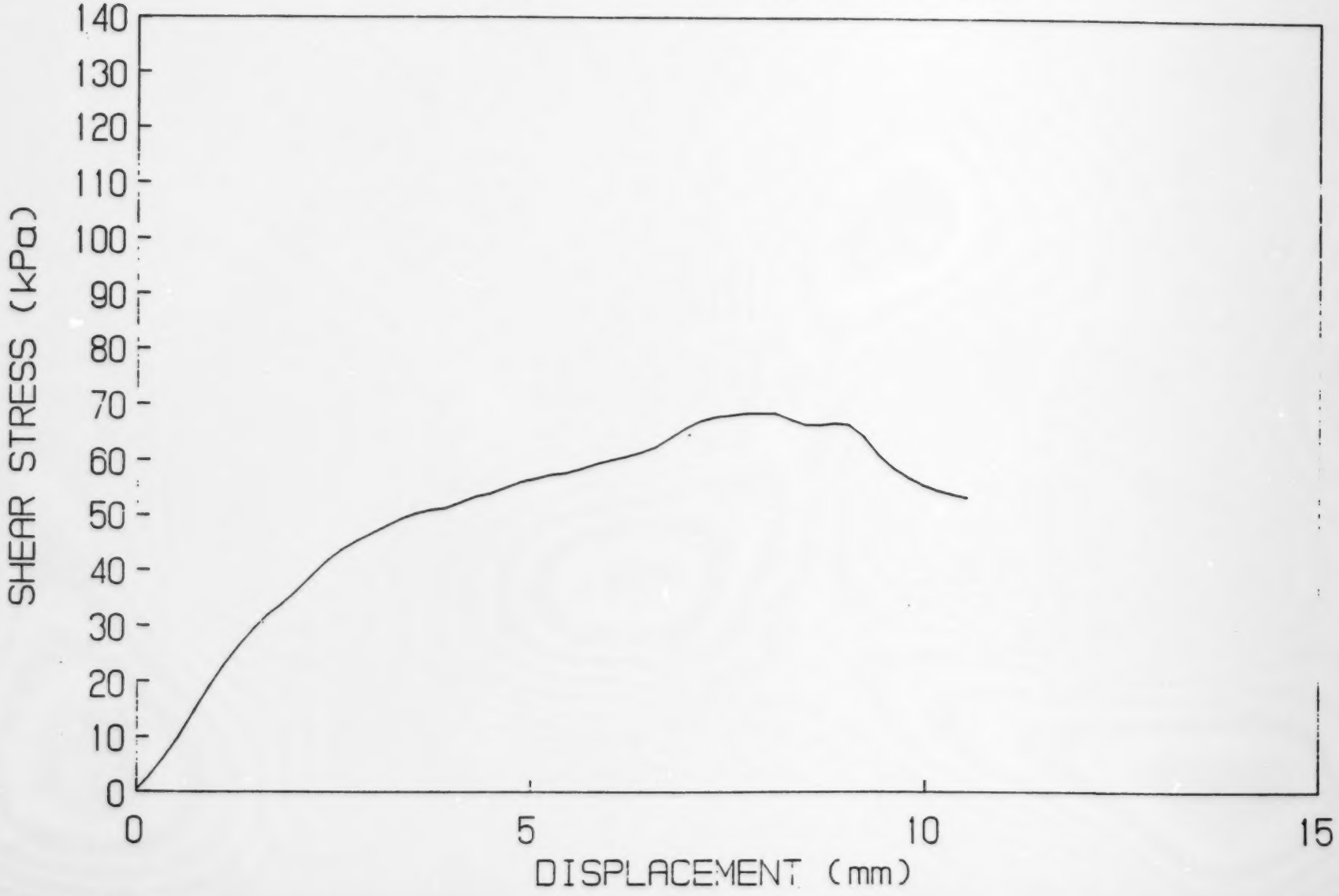
Normal Force: 46.84 kN

Density Before Applied Load: 1.86 g/cc
Density After Applied Load: 1.89 g/cc

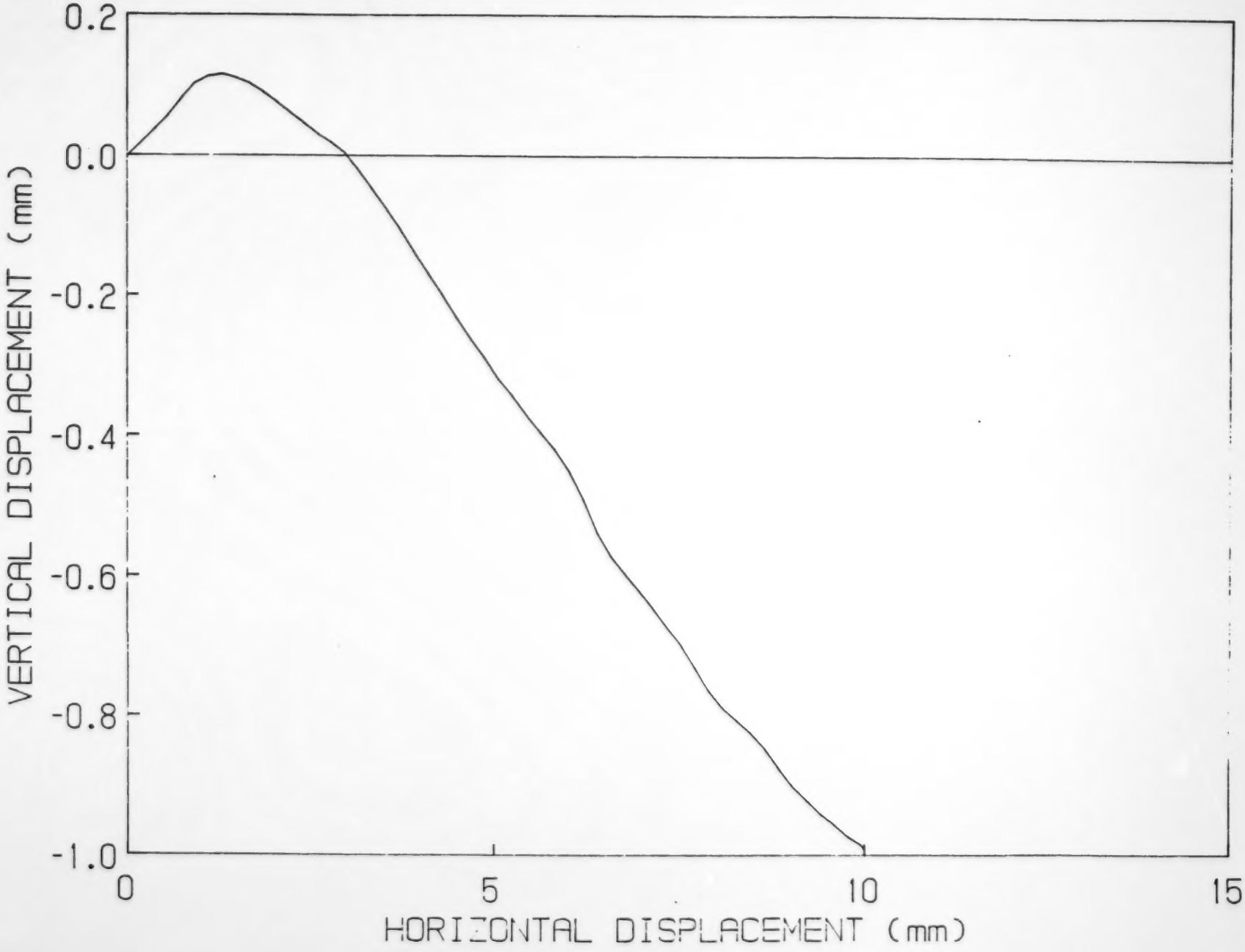
Int Ang Frict: 55.7 Degrees

SHEAR BOX TEST # 4

Compacted with 1.2 kPa Load
46.84 kPa Normal Load



SHEAR BOX TEST # 4



Test #: 5
Date: July 22, 1991
Project: Agnico-Eagle

Wt. of Beaker & Backfill: 744.0 g
Wt. of Beaker & Remainder: 262.5 g

Wt. of Fill in Shearbox: 481.55 g

Height from Top of Box: 0.694 cm
Change in Height w/ Applied Load: 0.44 cm

Volume of Material: 251.87 cc

Shearing Speed: 1.0 mm/min
Normal Load: 7.0 kg

TIME	VERTICAL DISPL.	FORCE (kN)	STRESS (kPa)
0	0.00	0.00	0.0
30	0.01	0.25	7.5
60	0.07	1.04	31.2
90	0.09	1.50	45.0
120	0.10	1.79	53.7
150	0.07	2.06	61.8
180	0.03	2.24	67.2
210	-0.02	2.40	72.0
240	-0.07	2.50	75.0
270	-0.13	2.63	78.9
300	-0.20	2.72	81.6
330	-0.28	2.76	82.8
360	-0.35	2.71	81.3
390	-0.41	2.82	84.6
420	-0.47	2.94	88.2
450	-0.53	3.02	90.6
480	-0.61	2.83	84.9
510	-0.68	2.70	81.0
540	-0.74	2.58	77.4
570			0.0
600			0.0
630			0.0
660			0.0
690			0.0
720			0.0
750			0.0
780			0.0
810			0.0
840			0.0

Max Shear Force: 3.02 mm (on proving ring)

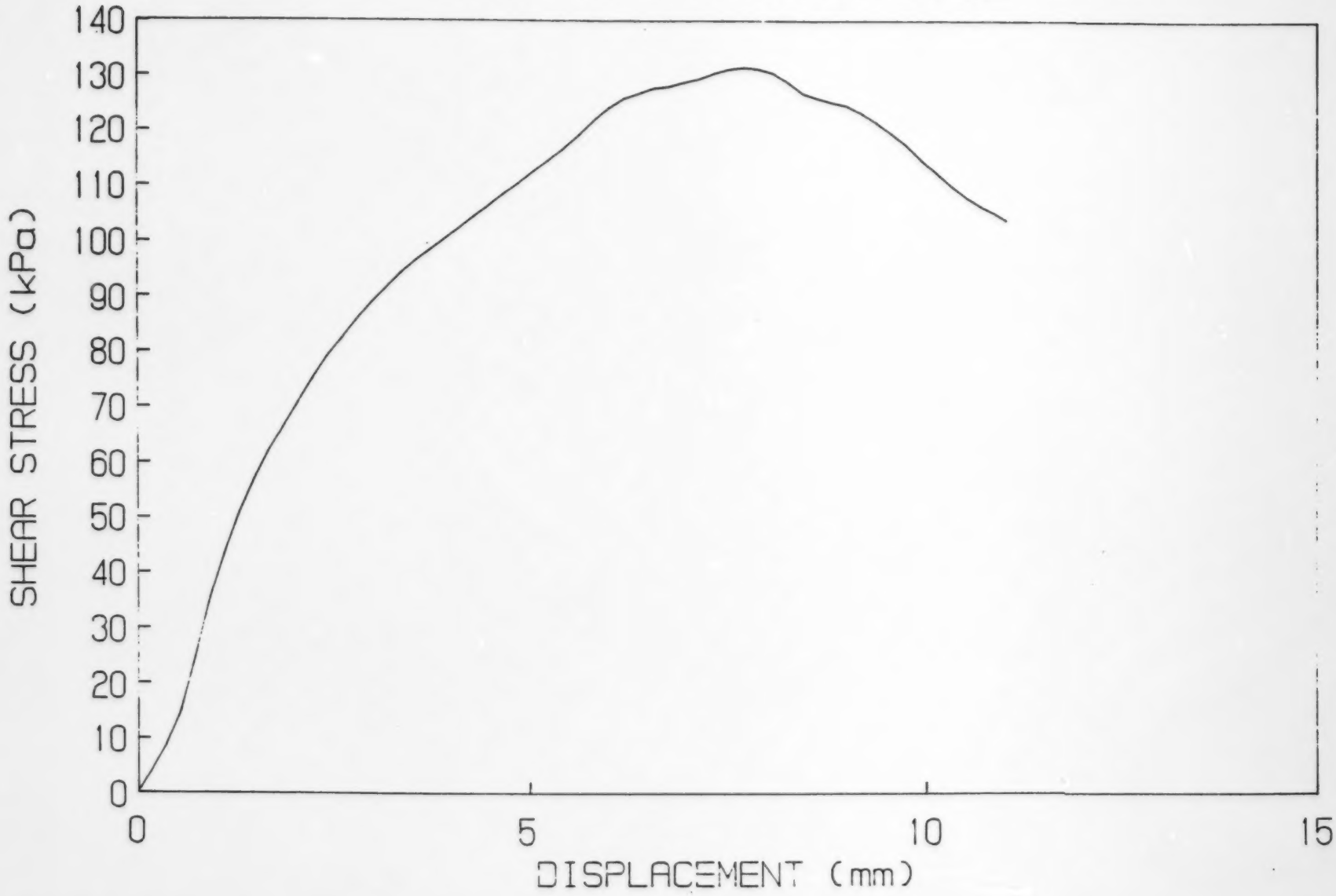
Normal Force: 76.24 kN

Density Before Applied Load: 1.91 g/cc
Density After Applied Load: 1.95 g/cc

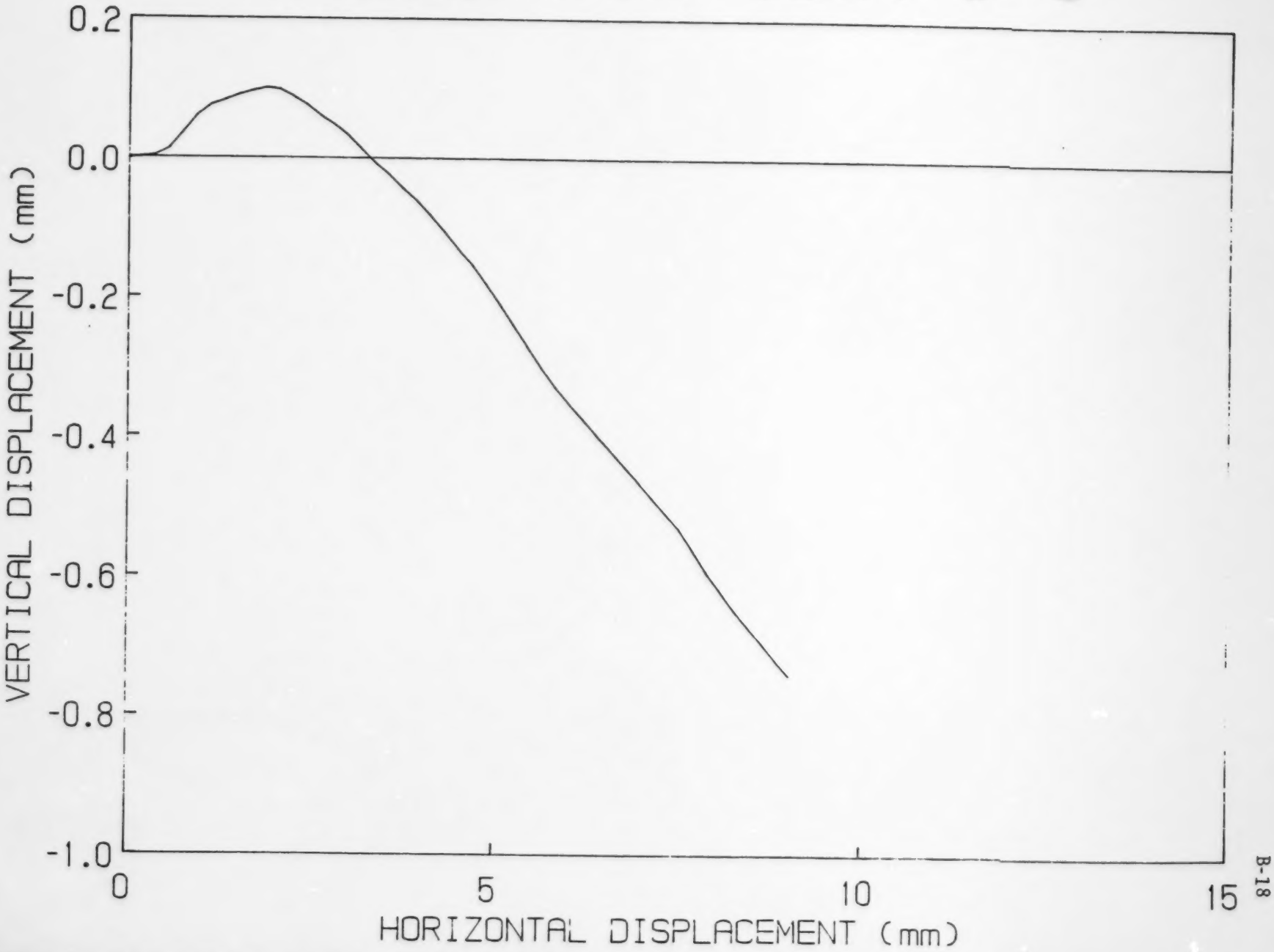
Int Ang Frict: 49.9 Degrees

SHEAR BOX TEST # 3

Compacted with 1.2 kPa Load
76.24 kPa Normal Load



SHEAR BOX TEST # 5



Test #: 6
Date: July 22, 1991
Project: Agnico-Eagle

Wt. of Beaker & Backfill: 1011.9 g
Wt. of Beaker & Remainder: 514.5 g
Wt. of Fill in Shearbox: 497.37 g

Height from Top of Box: 0.6 cm
Change in Height w/ Applied Load: 0.73 cm

Volume of Material: 261.27 cc

Shearing Speed: 1.0 mm/min
Normal Load: 10.0 kg

TIME	VERTICAL DISPL.	FORCE (kN)	STRESS (kPa)
0	0.00	0.00	0.0
30	0.01	0.44	13.2
60	0.07	1.31	39.3
90	0.11	1.91	57.3
120	0.13	2.32	69.6
150	0.14	2.68	80.4
180	0.13	2.97	89.1
210	0.10	3.20	96.0
240	0.07	3.38	101.4
270	0.02	3.56	106.8
300	-0.02	3.74	112.2
330	-0.07	3.92	117.6
360	-0.12	4.14	124.2
390	-0.18	4.25	127.5
420	-0.24	4.30	129.0
450	-0.29	4.37	131.1
480	-0.34	4.37	131.1
510	-0.39	4.21	126.3
540	-0.44	4.15	124.5
570	-0.49	4.01	120.3
600	-0.53	3.81	114.3
630	-0.56	3.60	108.0
660	-0.56	3.47	104.1
690			0.0
720			0.0
750			0.0
780			0.0
810			0.0
840			0.0

Max Shear Force: 4.37 mm (on proving ring)

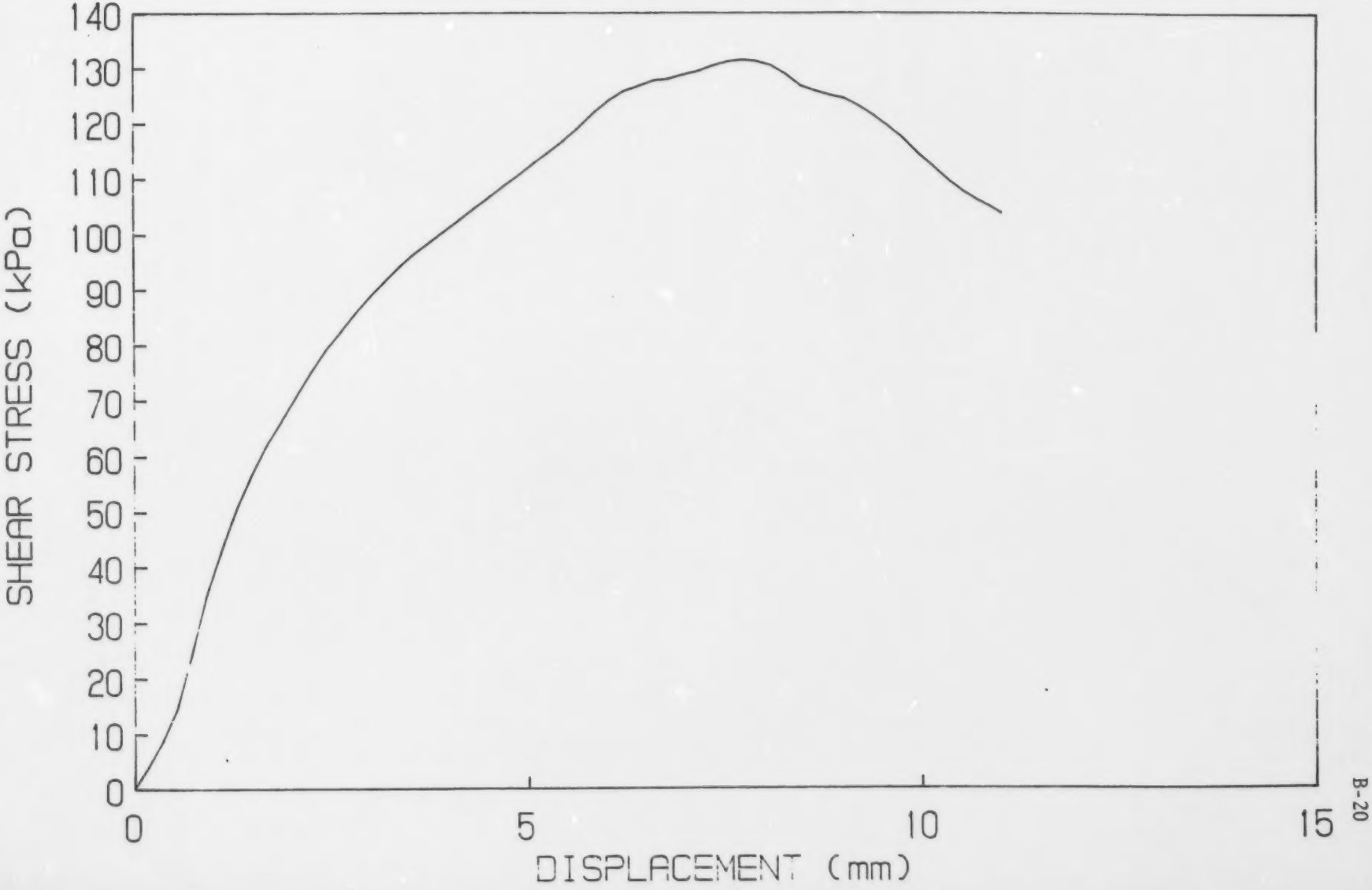
Normal Force: 105.64 kN

Density Before Applied Load: 1.90 g/cc
Density After Applied Load: 1.96 g/cc

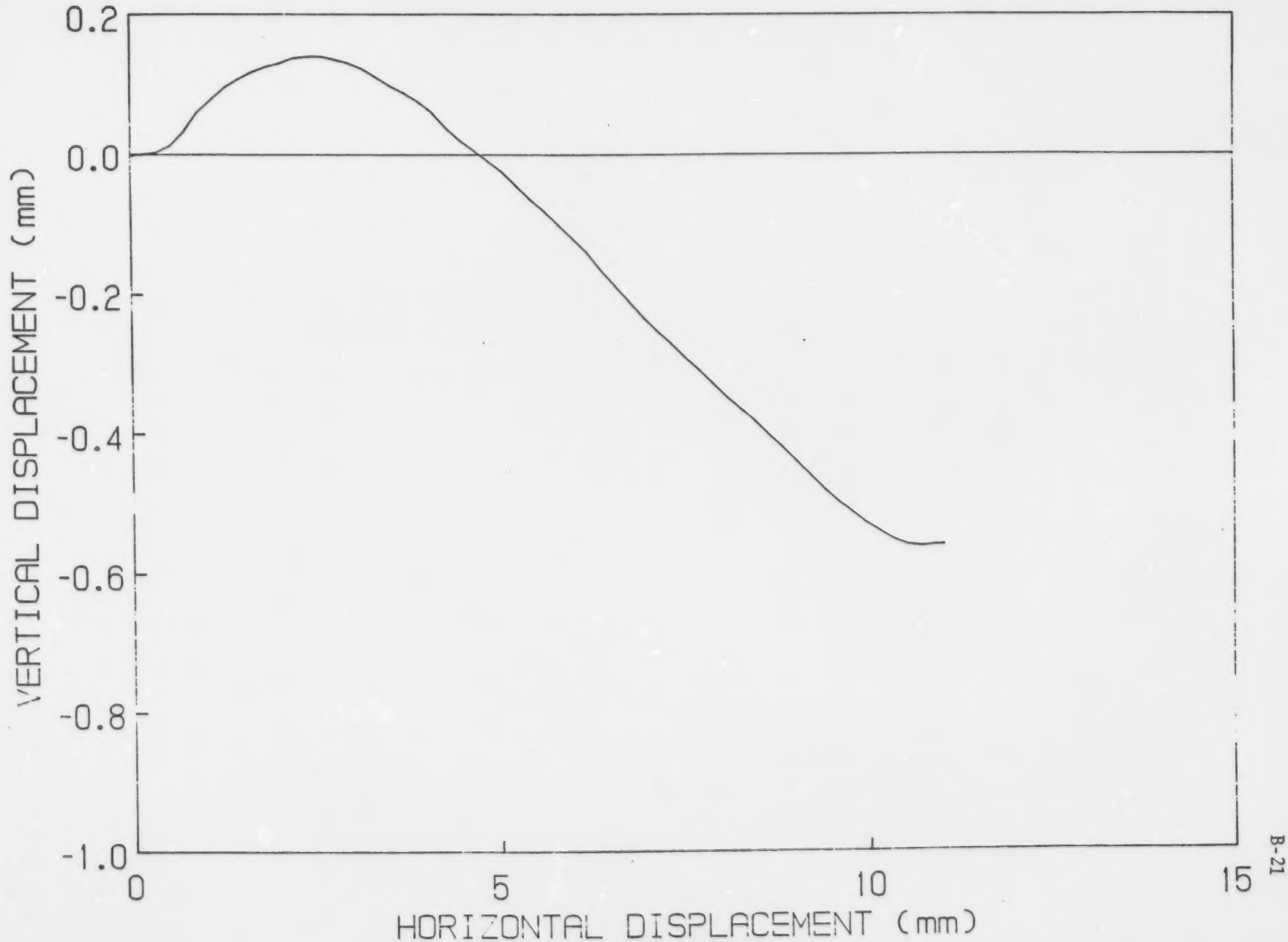
Int Ang Frict: 51.1 Degrees

SHEAR BOX TEST # 6

Compacted with 1.2 kPa Load
105.64 kPa Normal Load



SHEAR BOX TEST # 6



Test #: 7
Date: July 26, 1991
Project: Agnico-Eagle

Wt. of Beaker & Backfill: 3386.7 g
Wt. of Beaker & Remainder: 2906.4 g

Wt. of Fill in Shearbox: 480.30 g

Height from Top of Box: 0.241 cm
Change in Height w/ Applied Load: 2.04 cm

Volume of Material: 297.17 cc

Shearing Speed: 1.0 mm/min
Normal Load: 10.0 kg

TIME	VERTICAL DISPL.	FORCE (kN)	STRESS (kPa)
0	0.00	0.00	0.0
30	0.09	0.66	19.8
60	0.28	0.96	28.8
90	0.44	1.10	33.0
120	0.67	1.19	35.7
150	0.82	1.31	39.3
180	0.97	1.42	42.6
210	1.09	1.53	45.9
240	1.21	1.61	48.3
270	1.28	1.64	49.2
300	1.33	1.61	48.3
330	1.34	1.54	46.2
360	1.34	1.48	44.4
390	1.34	1.45	43.5
420	1.35	1.45	43.5
450	1.35	1.44	43.2
480	1.35	1.45	43.5
510	1.35	1.45	43.5
540	1.35	1.48	44.4
570	1.35	1.52	45.6
600	1.35	1.53	45.9
630	1.35	1.51	45.3
660	1.35	1.51	45.3
690	1.35	1.49	44.7
720	1.35	1.50	45.0
750	1.35	1.53	45.9
780			0.0
810			0.0
840			0.0

Max Shear Force: 1.64 mm (on proving ring)

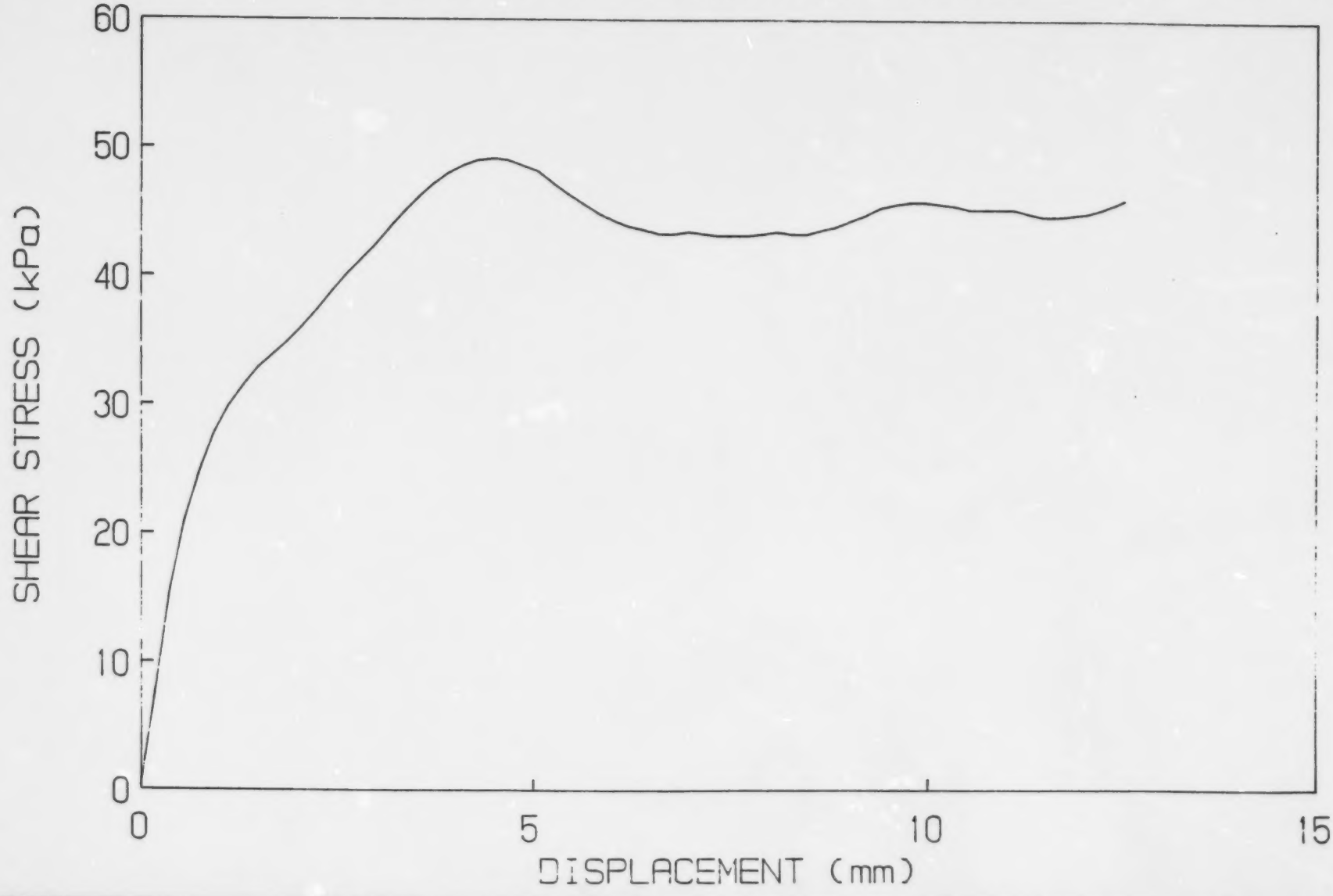
Normal Force: 105.64 kN

Density Before Applied Load: 1.62 g/cc
Density After Applied Load: 1.74 g/cc

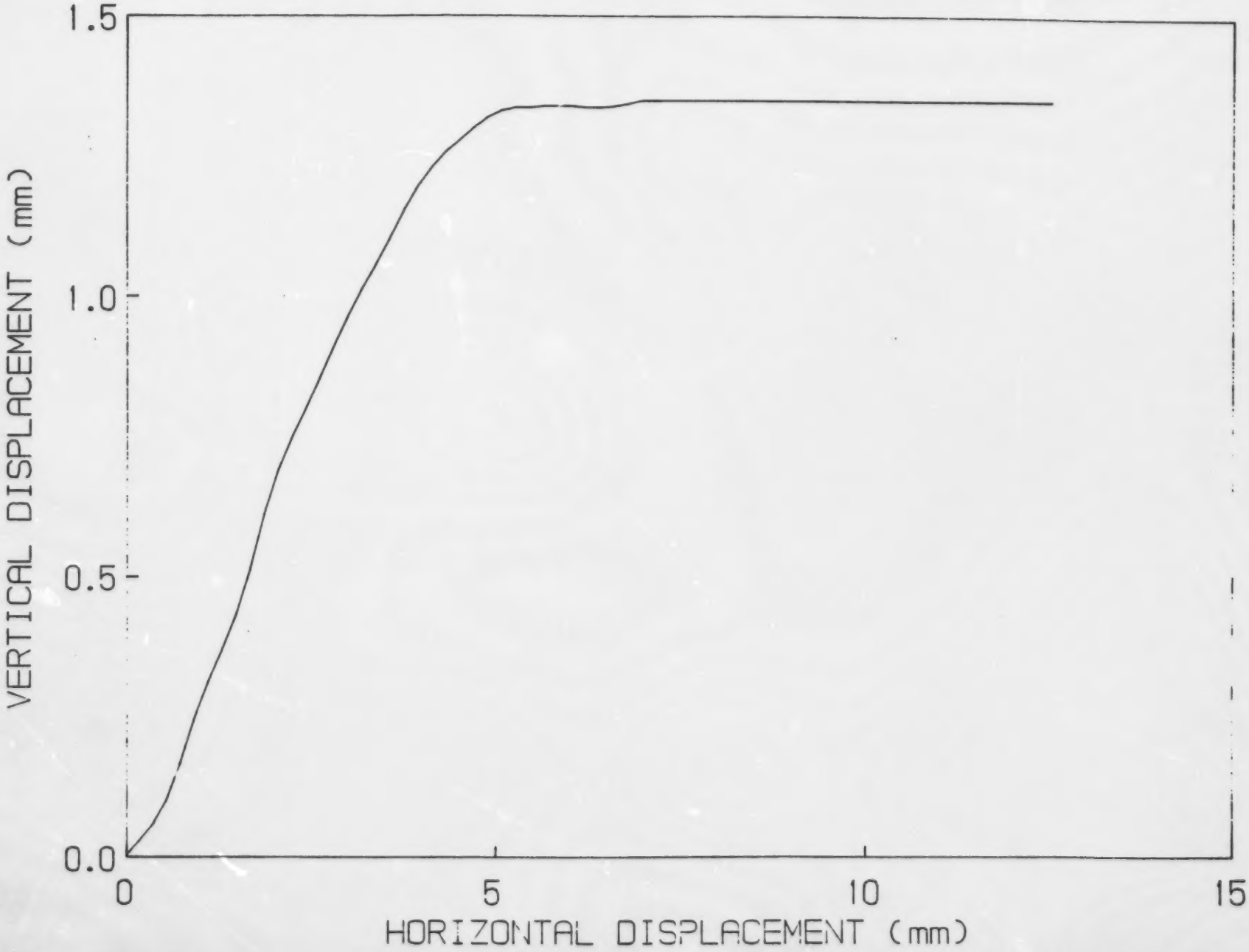
Int Ang Frict: 25.0 Degrees

SHEAR BOX TEST #7

Compacted, Wet Material
105.64 kPa Normal Stress



SHEAR BOX TEST # 7



Test #: 8
Date: July 26, 1991
Project: Agnico-Eagle

Wt. of Beaker & Backfill: 3353.4 g
Wt. of Beaker & Remainder: 2906.4 g
Wt. of Fill in Shearbox: 447.03 g

Height from Top of Box: 0.435 cm
Change in Height w/ Applied Load: 0.92 cm

Volume of Material: 277.77 cc

Shearing Speed: 1.0 mm/min
Normal Load: 7.0 kg

TIME	VERTICAL DISPL.	FORCE (kN)	STRESS (kPa)
0	0.00	0.00	0.0
30	0.06	0.03	0.9
60	0.09	0.20	6.0
90	0.25	0.56	16.8
120	0.43	0.76	22.8
150	0.59	0.89	26.7
180	0.60	1.01	30.3
210	0.61	1.08	32.4
240	0.61	1.15	34.5
270	0.61	1.20	36.0
300	0.61	1.22	36.6
330	0.61	1.20	36.0
360	0.61	1.19	35.7
390	0.61	1.12	33.6
420	0.61	1.12	33.6
450	0.61	1.15	34.5
480	0.61	1.12	33.6
510	0.61	1.11	33.3
540	0.61	1.12	33.6
570	0.61	1.08	32.4
600	0.61	1.08	32.4
630	0.61	1.07	32.1
660	0.61	1.07	32.1
690	0.61	1.08	32.4
720			0.0
750			0.0
780			0.0
810			0.0
840			0.0

Max Shear Force: 1.22 mm (on proving ring)

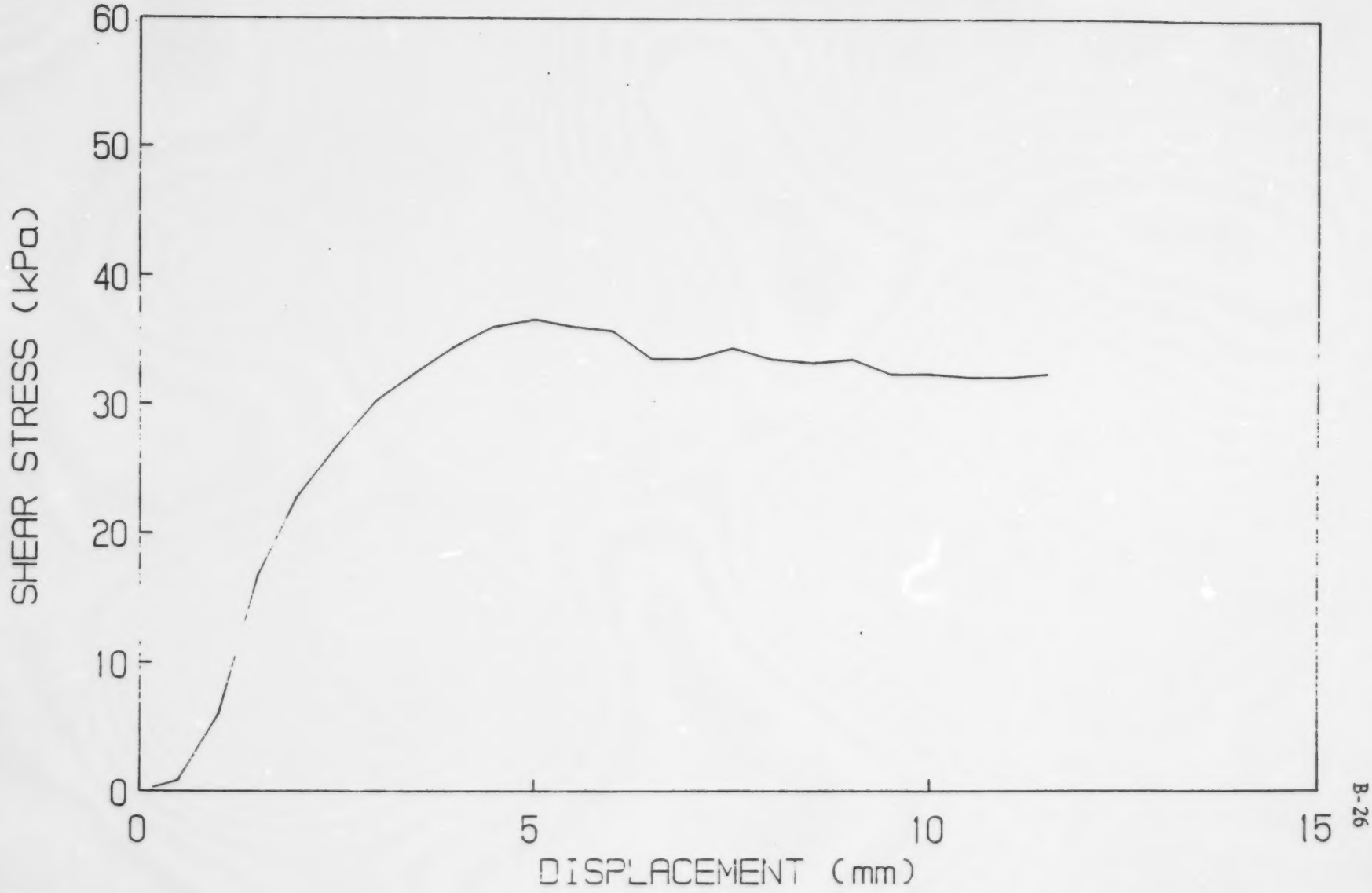
Normal Force: 76.24 kN

Density Before Applied Load: 1.61 g/cc
Density After Applied Load: 1.66 g/cc

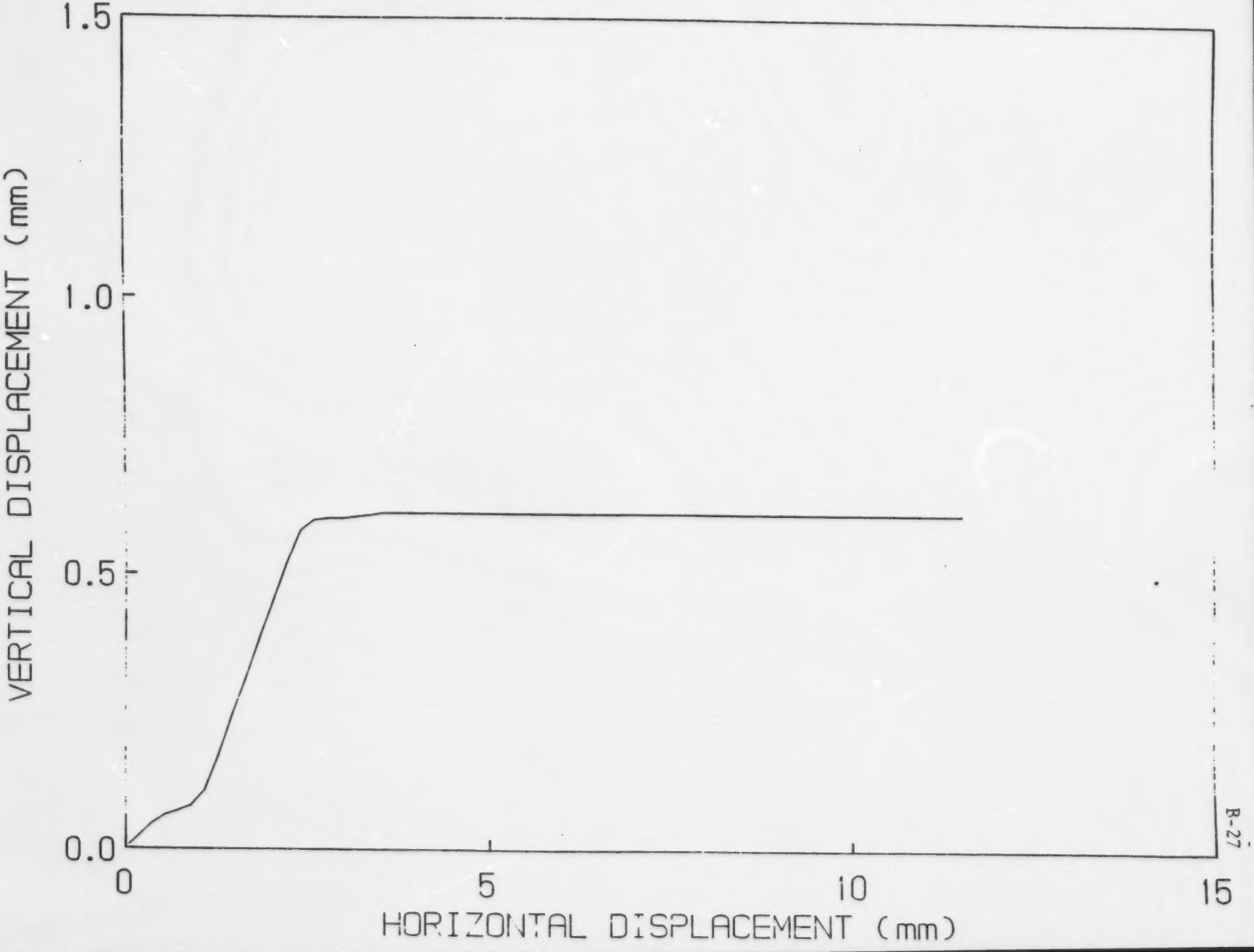
Int Ang Frict: 25.6 Degrees

SHEAR BOX TEST # 8

Compacted, Wet Material
76.24 kPa Normal Stress



SHEAR BOX TEST # 8



Test #: 9
Date: July 25, 1991
Project: Agnico-Eagle

Wt. of Beaker & Backfill: 3373.0 g
Wt. of Beaker & Remainder: 2905.2 g
Wt. of Fill in Shearbox: 467.80 g

Height from Top of Box: 0.409 cm
Change in Height w/ Applied Load: 0.44 cm

Volume of Material: 280.37 cc

Shearing Speed: 1.0 mm/min
Normal Load: 4.0 kg

TIME	VERTICAL DISPL.	FORCE (kN)	STRESS (kPa)
0	0.00	0.00	0.0
30	0.01	0.01	0.3
60	0.05	0.05	1.5
90	0.10	0.30	9.0
120	0.14	0.47	14.1
150	0.18	0.56	16.8
180	0.22	0.62	18.6
210	0.25	0.63	18.9
240	0.28	0.70	21.0
270	0.30	0.73	21.9
300	0.32	0.77	23.1
330	0.34	0.77	23.1
360	0.35	0.78	23.4
390	0.37	0.80	24.0
420	0.39	0.82	24.6
450	0.40	0.84	25.2
480	0.41	0.86	25.8
510	0.41	0.89	26.7
540	0.41	0.91	27.3
570	0.41	0.92	27.6
600	0.40	0.93	27.9
630	0.40	0.93	27.9
660	0.41	0.95	28.5
690	0.41	0.98	29.4
720	0.41	1.02	30.6
750	0.42	1.06	31.8
780	0.42	1.08	32.4
810			0.0
840			0.0

Max Shear Force: 1.08 mm (on proving ring)

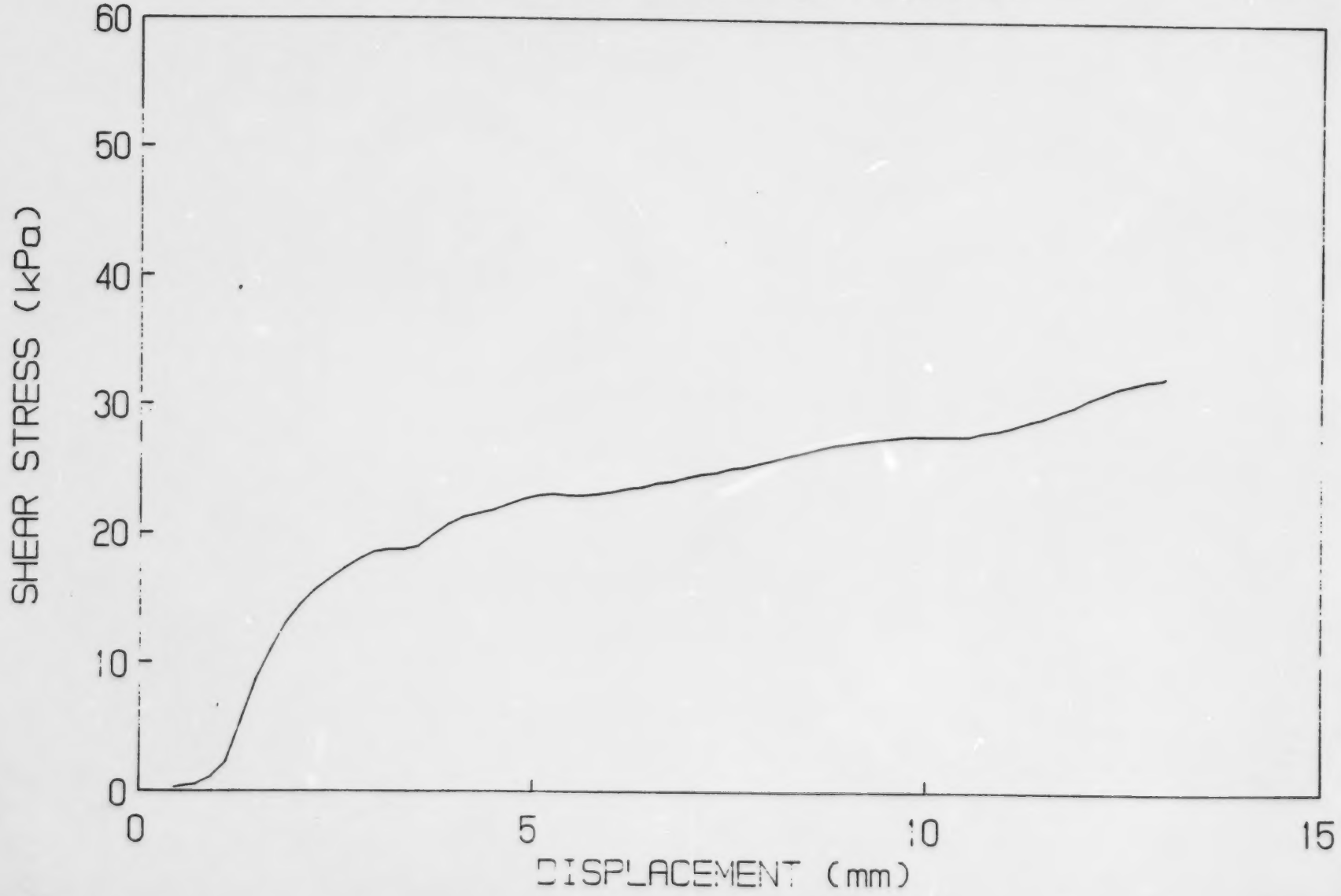
Normal Force: 46.84 kN

Density Before Applied Load: 1.67 g/cc
Density After Applied Load: 1.70 g/cc

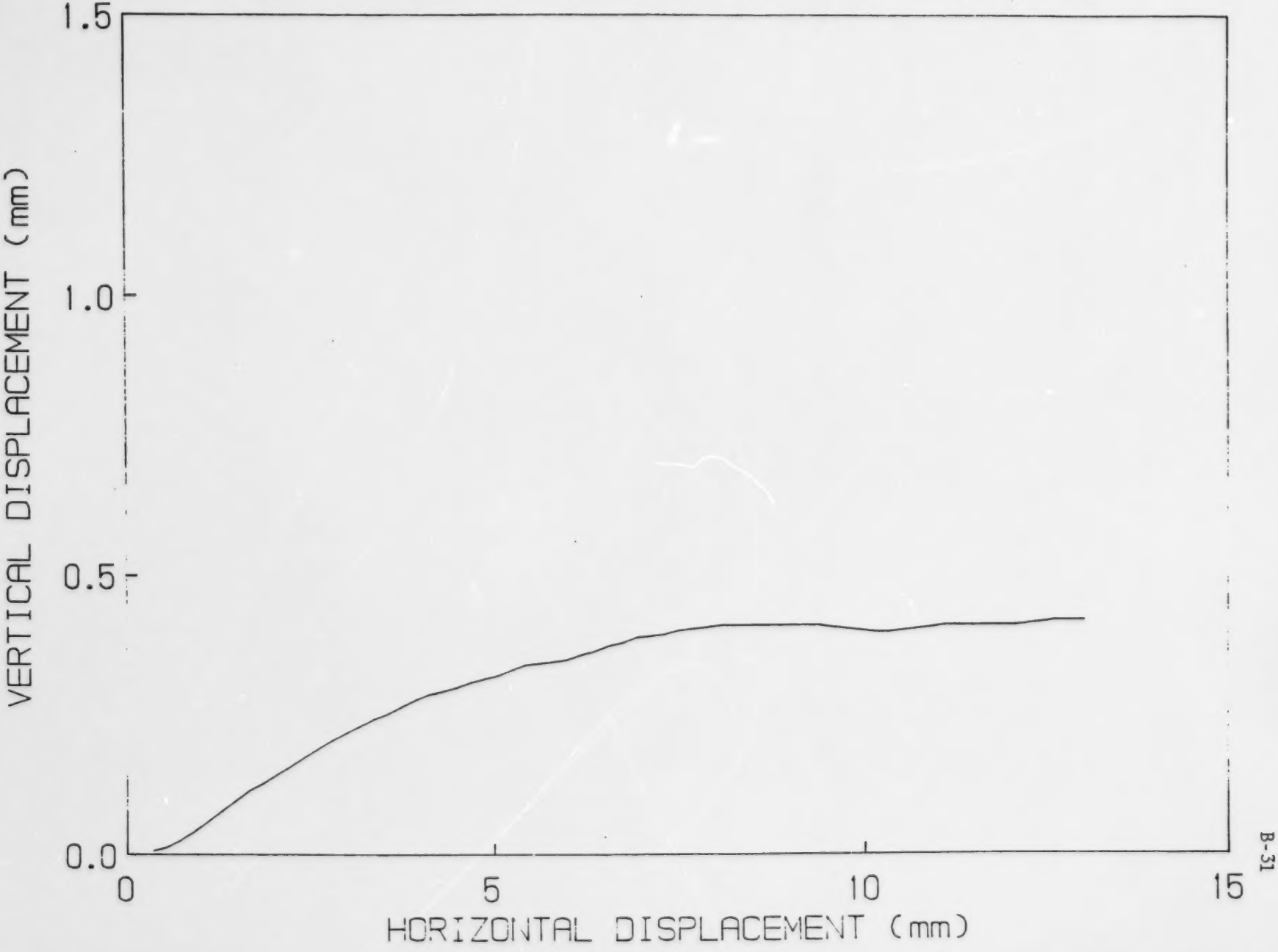
Int Ang Frict: 34.7 Degrees

SHEAR BOX TEST # 9

Compacted, Wet Material
46.84 kPa Normal Stress



SHEAR BOX TEST # 9



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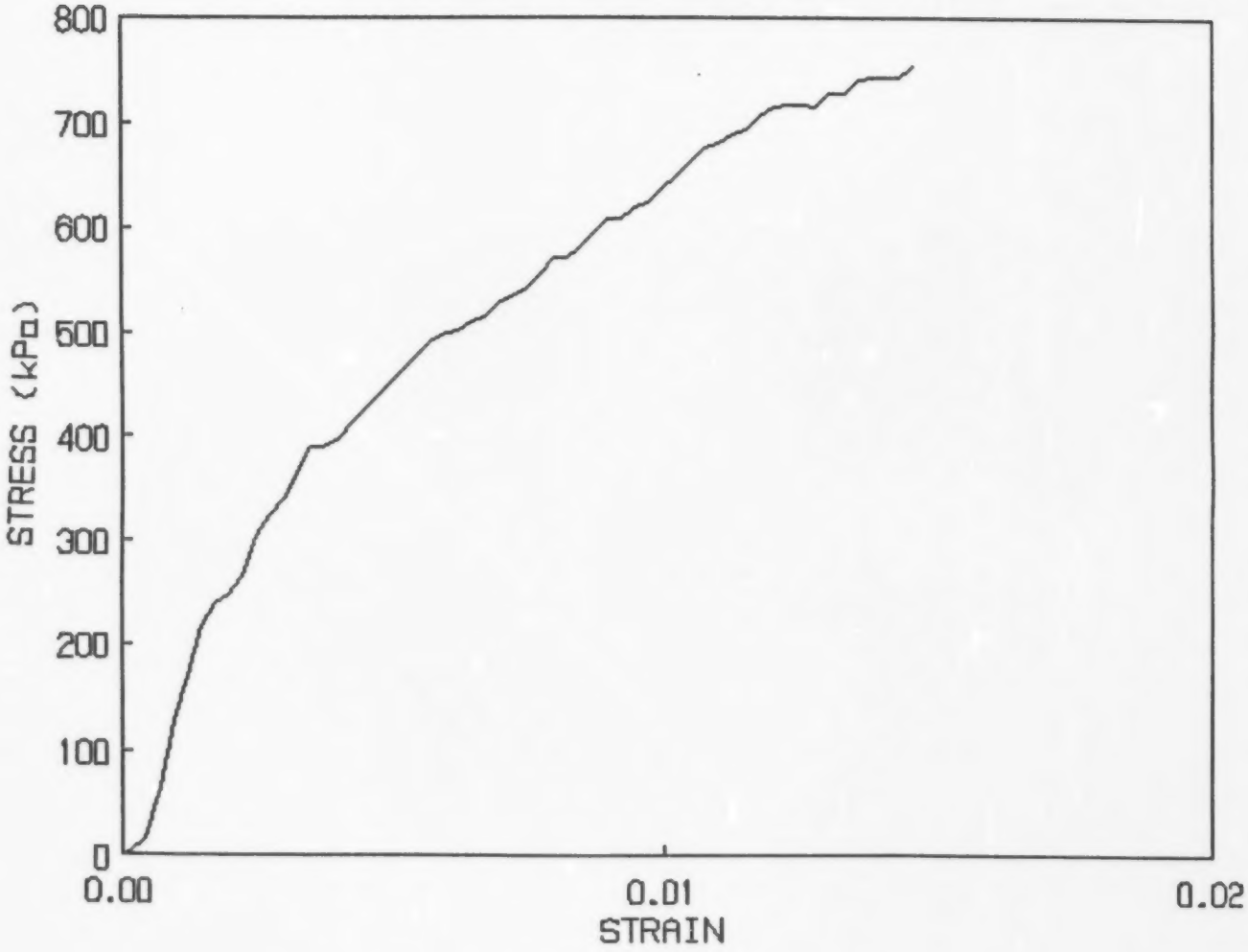
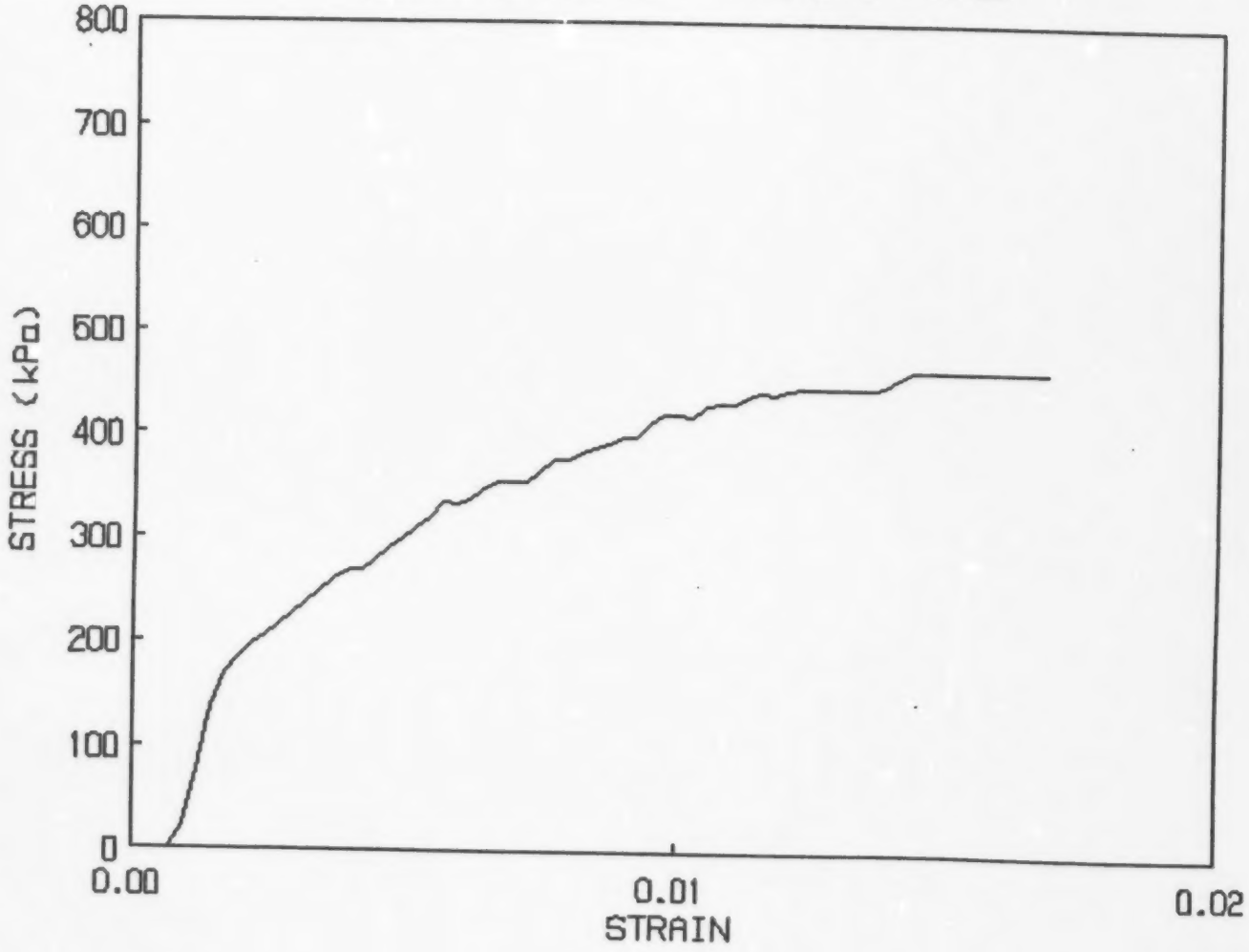
APPENDIX C

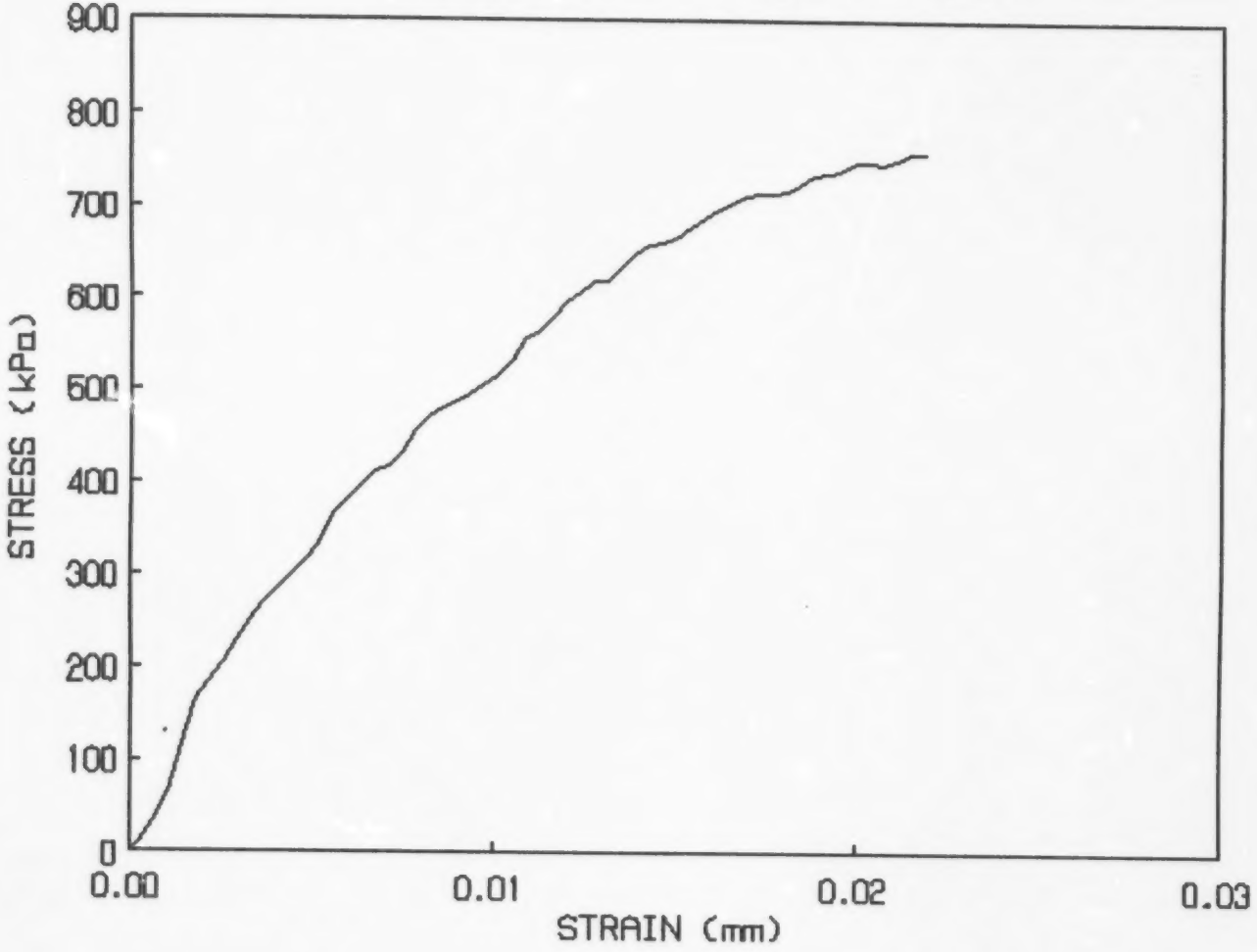
TRIAXIAL TEST #1



TRIAXIAL TEST #2

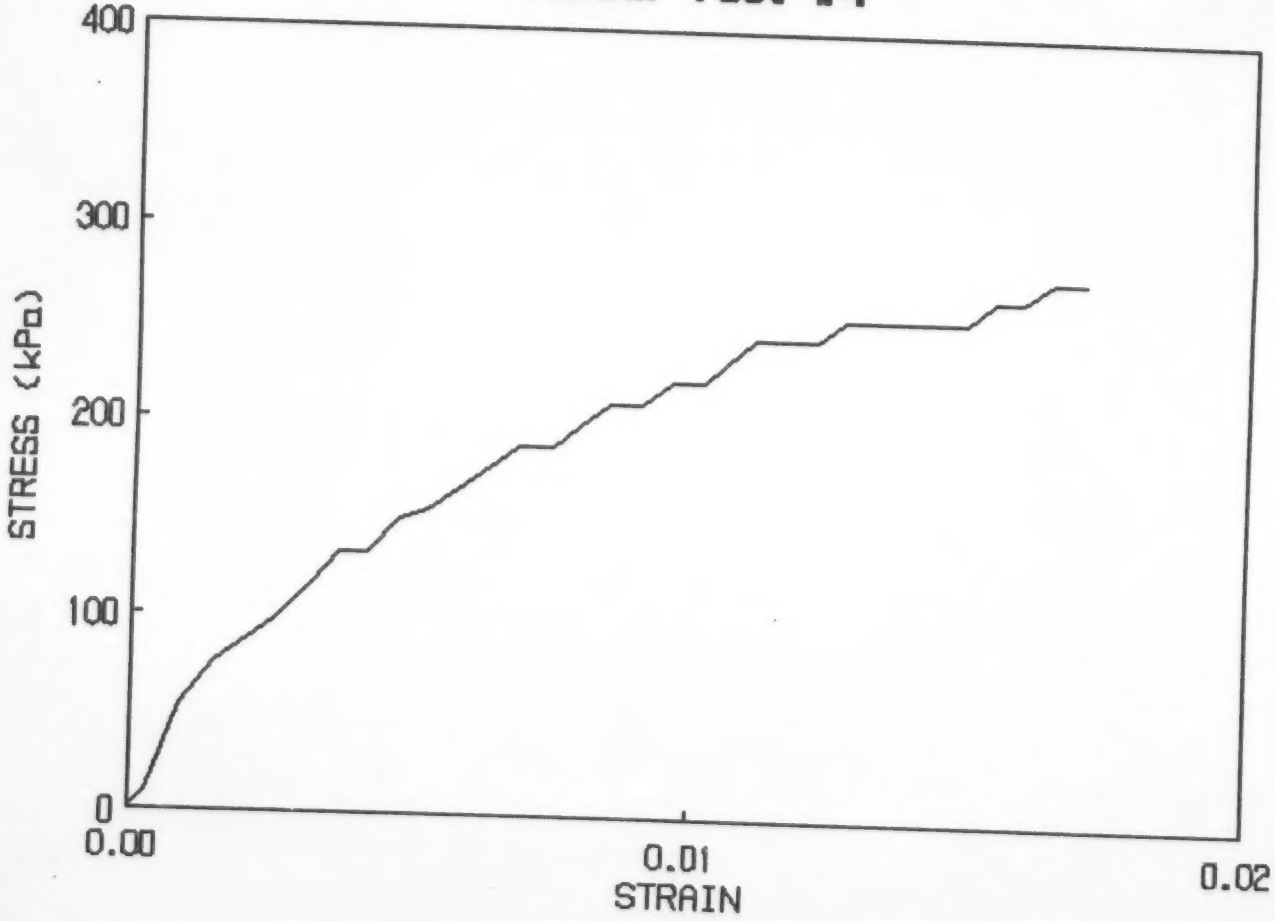


TRIAXIAL TEST #3



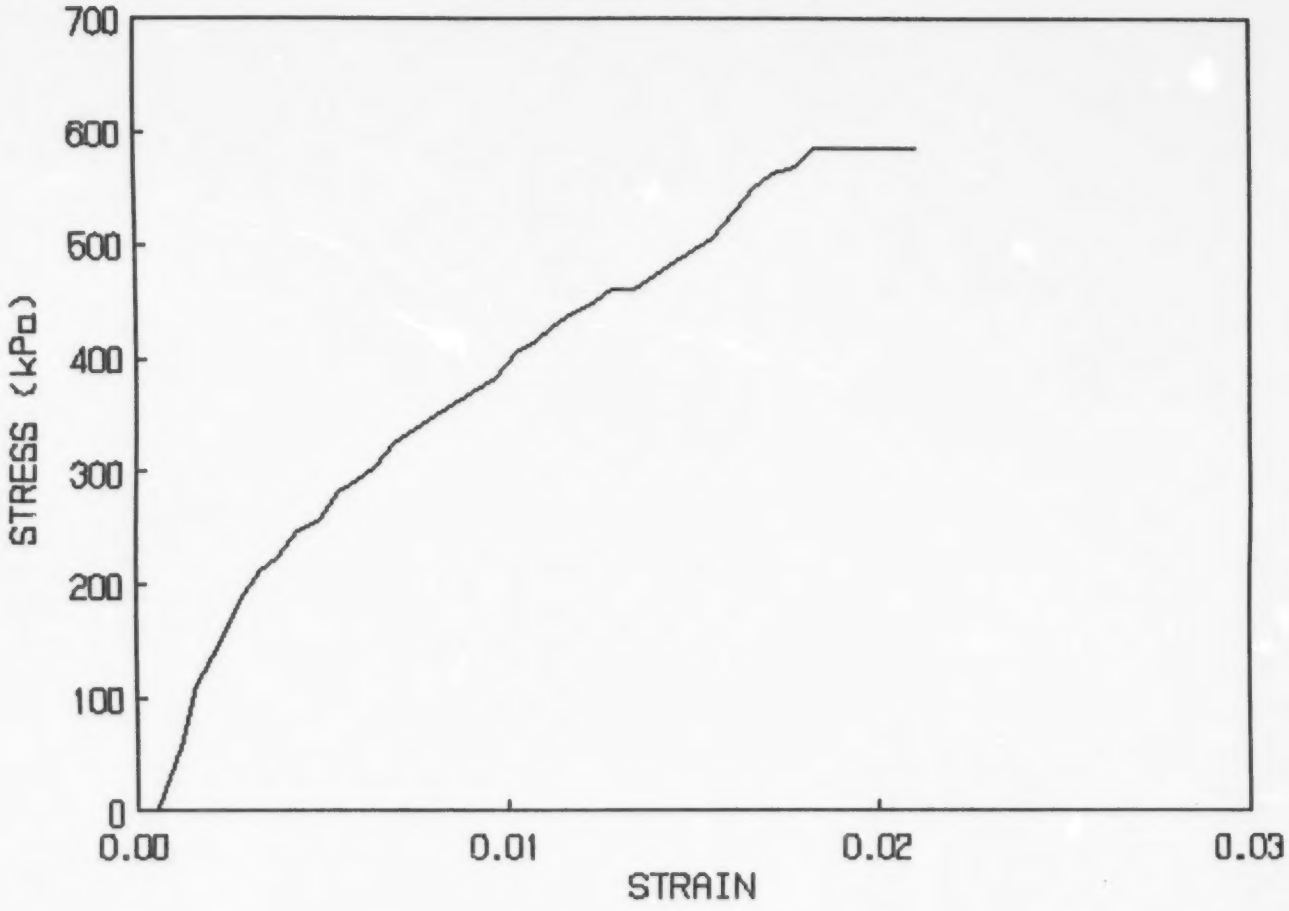
AGNICO-EAGLE

Triaxial Test #4



AGNICO-EAGLE

Triaxial Test #5



AGNICO-EAGLE

Triaxial Test #6